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STUDIES IN INDIAN SUGARCANES, No. 2

SUGARCANE SEEDLINGS, INCLUDING SOME CORRELATIONS BETWEEN MORPHOLOGICAL CHARACTERS AND SUCROSE IN THE JUICE

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INTRODUCTION.

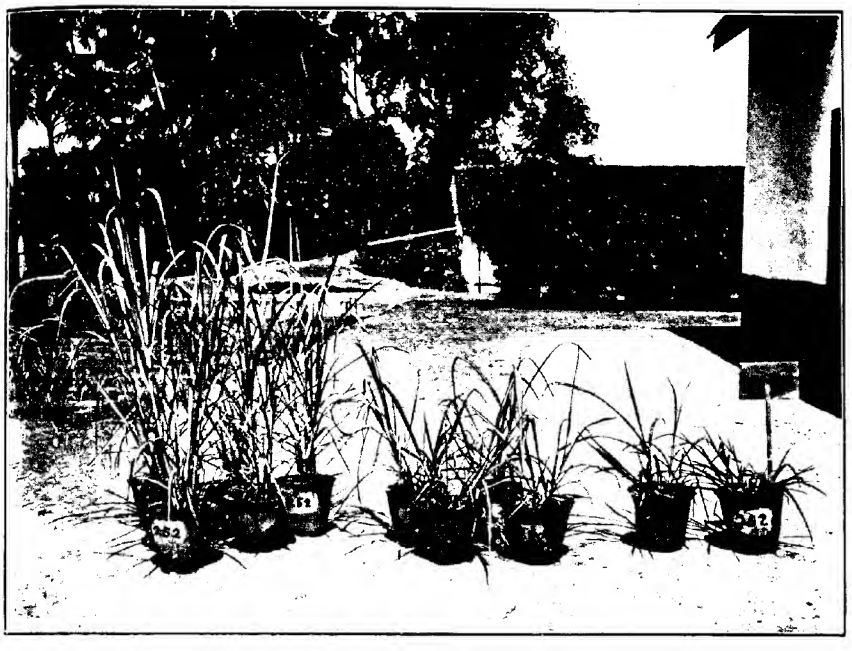
ONE of the most striking features in any batch of young seedlings, raised from common parents, is the variation among them in small particulars. This is true of cane seedlings as well as of other plants (Pl. I). They differ in size and shape, width of leaf and thickness of stem, colour marks in various parts and habit in general. As to the latter, the seedlings may vary from upright bushes to oblique, sprawling or prostrate. The tips of their leaves may be strict, erect, rapier, or bayonet-like in their rigidity, sharply bent or curving broadly and gracefully. The colour of their stems may be yellow, green, or white, tinged with pink, purple, red or claret, striped in various ways, shiningly smooth or thickly coated with white waxy bloom. The leaf-sheaths are less easy to describe, but here, too, we find all variations in colour between light green and dark chocolate purple, through various stages of reds and blues.

We now know, from the chemical analysis of these seedlings at harvest, that their juice also varies extraordinarily in the quantity of sugar that it contains. This is in keeping with the fact, noted in other cultivated plants, that seedlings tend to vary most in the character for which they have been selected. And the temptation is irresistible to try and correlate the various infantile characters mentioned above with the richness of the juice of the mature plant at crop time. Such an endeavour is, however, fraught with

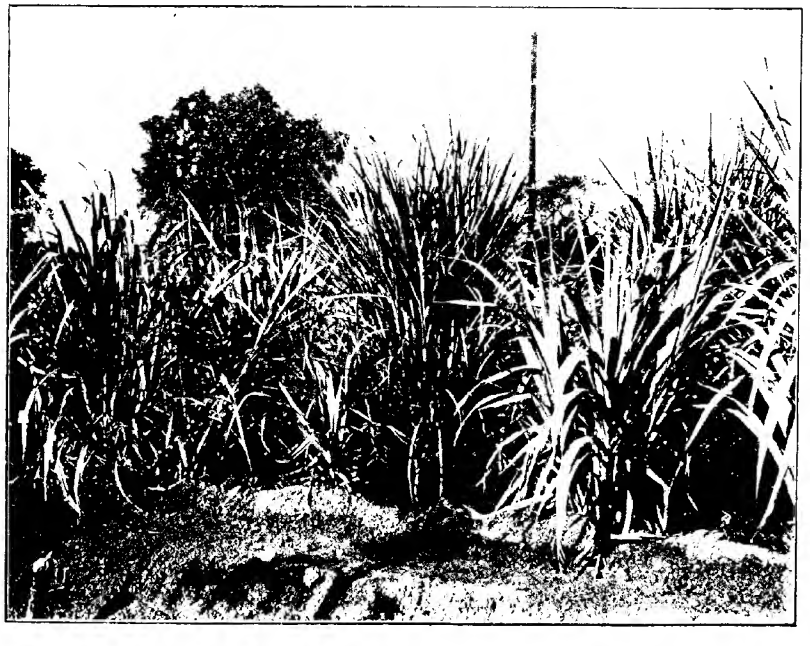
difficulty, and yet any success in such correlation will obviously be of the greatest assistance in the early selection of new and better canes for cultivation. An enormous amount of labour is now being devoted to work of this kind, especially in the United States of America, where, among many other plants, apple trees are minutely studied in the seedling stages to try and find early indications of good new varieties. The work of cane-breeding, as compared with that of most other plants, is characterized by its extreme slowness, and any means of quickening its progress will be of great value. To grow a seedling cane from seed to maturity and to analyse its juice takes up the best part of two years. It is even then impossible to gauge its ultimate value, as it is necessary to cultivate it for several successive seasons before the natural vigour of the seedling has abated and its true growth character is understood, so that it can be put out for further trial on a crop scale in the fields. Such is the experience gained after a quarter of a century of work in this direction, and any attempt at shortening the period of testing is subject to the danger of distributing unsuitable varieties, and thus raising doubts as to the advantages to be gained by this method of improving the industry.

Comparisons are often made between the relative progress in the improvement of sugarcanes and sugar beets by the selection of seedlings. We must, however, at the outset, bear in mind that, while the beet was practically a wild plant as regards sugar content a hundred years ago, selection in the cane for sugar extends to the remotest past. It is an unfortunate fact that, despite the enormous number of cane seedlings raised, we have not made any marked progress in our search for canes with richer juice which are at the same time profitable in cultivation. The average sugar content of the canes cultivated is not appreciably greater than it was before the first seedlings were raised. The great forward strides made in the industry by the introduction of seedling canes have been rather in the direction of obtaining sound canes yielding a certain crop, one less liable to the ups and downs caused by weather and disease. The former, time-honoured, method of selection was slow and sure, but it was eminently successful, and it may take us many years before we can emulate it by producing such magnificent canes as the *Bourbon* and *Cheribon*, guaranteed to maintain their high qualities for the best part of a century. With the crop assured, however, immense advances have also been made possible in the directions of management, machinery and cultivation. In the sugar beet, the quantity of sugar in the roots has been enormously increased by a system of suitable selection. But it takes little thought to see that the conditions of the two rivals, apart from their history, are intrinsically different.

PLATE I.



Pansahi Seedlings (1914-16), 4 months old, showing variation in habit, size, erectness, etc.



Ashy Mauritius Seedlings (1913-15), 10 months old, showing similar variations, as well as, markedly, in width of leaf.

With a rapidly maturing and heavily seeding plant like the beet, selection work among seedlings is a very different thing from that possible in the sugarcane, which rarely flowers and takes so long to mature its seed and adapt itself to field cultivation. Anything like progressive selection is ruled out at once. If we could guarantee that every seedling would flower and produce seed in due course, progress would be as certain as in the beet, although perhaps a good deal slower. But, unfortunately, it happens that, once a seedling of value is obtained, it is a matter of considerable doubt whether it will ever flower and, if it does, whether the flowers will be fertile, and further improvement along this line is checked. We are, so to speak, confined to a series of first steps in progress. The sugarcane has, however, one advantage, namely, in its *vegetative reproduction*. Once a better variety is obtained, it can be reproduced with a fair promise of its maintaining its good qualities. Even here, it has been shown that deterioration may soon set in and that the length of useful life in good, new seedlings is limited.[1] Summing up our comparison, in the cane, as contrasted with the beet, it is far more difficult to obtain improvement by seed selection, but, once it is obtained, it is easier to maintain it; all of which brings it home afresh that it is of the first importance to quicken the process of selection.

On pondering over a fresh batch of seedlings, there is nothing to indicate the character which will be assumed at maturity. The quality of the juice is also completely masked and, even at crop time, we are quite in the dark, before cutting the cane, as to what amount of sugar it will be found to contain. It has, indeed, too often happened that an apparently ideal seedling, erect, free-growing and healthy, has turned out to have such poor juice that it would be profitless to grow it further, whereas a struggling and badly shaped plant may, on analysis, show excellent juice, awakening the suspicion that vigour and richness are conversely related. It appears as if there is but one way, in the absence of the intuition of a Burbank, in which to attack this problem—the correlation of infant morphological characters with ultimate value. Firstly, it is necessary to make a full study of the characters of seedlings *at maturity* and, after analysis of the juice, to compare these characters individually with the quality of this juice, on the chance of obtaining some correlation between them. For instance, to determine whether the width of the leaf in any batch of seedlings is correlated with the amount of sucrose in the juice, the average leaf width of each seedling must be obtained by suitable

1 Harrison, Stockdale and Ward. Sugarcane Experiments in British Guiana. *West Indian Bulletin*, XIII, 2, 1912.

measurements, and the whole number arranged in a series of classes of increasing leaf width, commencing with the narrowest and proceeding to the widest. Opposite to these must then be placed the sucrose percentage in the juice of each seedling and averages struck for each class (*cf.* p. 167). By a comparison of these averages, it will be possible to determine whether there is a gradual increase or decrease in the richness of the juice along the series, and thus to establish a positive or negative correlation between sucrose percentage and leaf width. As a matter of fact, such a correlation appears to exist, as will be detailed later, in that the narrow-leafed seedlings of any one batch with common parentage have richer juice than the broad-leafed, that is, there is a negative correlation between width of leaf and sucrose in the juice. Secondly, we shall have to hark back and see how far the correlated characters of mature seedlings can be traced into their early stages, how far down the life-history of the individual we may be able to foretell the mature characters.

An attempt has been made in the concluding section of this paper to deal with the first part of the problem, and it is believed that certain correlations have been detected between the external appearance of the seedling at crop time and the richness of the juice. These results are based chiefly on a study of the seedlings analysed during 1914, certain characters having been recorded at crop time according to a detailed plan, drawn up after the study of the main differences in the groups of indigenous canes in India. The characters dealt with in this paper are chiefly quantitative, that is measurements of different kinds. The qualitative characters are, in the sugarcane, much more difficult to observe, but they will be attacked in due course as data accumulate.

A considerable space is given in the present paper to the study of the chemical analysis of the juice of the seedlings. The following is an enumeration of the number of complete analyses of juice of seedlings and varieties made on the Cane-breeding Station during the last three years: –1913, 92; 1914, 2,099; 1915, 4,005. There is one chemical assistant attached to the office of the Government Sugarcane Expert, and, as most of these analyses are made during four or five months of the year, it is obvious that he is quite unable to cope with the work. By a rearrangement of the planting programme, the analyses of seedlings and varieties of canes will be spread out, so that the analyses of the former will be made mostly after the varieties have been finished. But, even then, the great pressure of work at the time of harvesting the seedlings necessitates assistance from outside, and this has been generously supplied by Dr. Harrison, the Government

Agricultural Chemist, two of whose assistants have been lent each year during the time of greatest pressure.

It will be seen, from the ensuing tables, that, although an increasing number of seedlings are dealt with during each season, a very large number have to be rejected owing to the impossibility of analysing them. This is a great handicap for, other things being equal, the larger the number of seedlings tested, the greater is the number likely to be of ultimate value. The abbreviation of the chemical work has therefore received very careful attention, and it is hoped that considerable progress is being made in this direction, without impairing the efficiency of the selection work. It has been found that the analysis at crop time does not always give a fair account of the richness of the juice in any seedling, and a series of preliminary or petty analyses have been introduced, as is shown in the section dealing with the chemical character of the juice. Owing to the pressure during the past season, a rule has been instituted that, in petty analysis, seedlings with less than a certain proportion of total solids for each batch are not proceeded with further until the harvest, when all are analysed (bulk analysis). This saves considerable time, and the petty analysis can be much more rapidly pushed through. Secondly, greater care is being taken in the selection of canes for analysis. It has been shown, in a Memoir on the Punjab Canes[1], that in the varieties grown there, two classes of canes are often distinguishable in the field at crop time, termed "early" and "late." A study of the varieties and seedlings grown on the Cane-breeding Station shows that this character of the cane is present here also in many cane varieties, and care is taken to choose early canes in all cases of petty analysis. This tends to rule out the extraordinary variations met with in successive analyses of the same seedling, thereby obviating the need for confirmatory tests. Thirdly, considering the cane plant as theoretically made up of a series of more or less independent phytomers (each consisting of a joint and the leaf attached to it), a progressive ripening of the cane from below upwards has been assumed, and it has been postulated that those parts of the cane where the leaves have died are, to all intents and purposes, ripe. If this is the case, we have a means of early detecting the character of the juice of any cane, and analyses "up to dead leaf" have been made in a considerable number of cases, with fairly confirmatory results. By this means it is hoped that an early estimate may be formed, at any rate as to the *ultimate* character of the juice, easily the most important feature in any cane intended for cultivation.

[1] Barber, C. A. Studies in Indian Sugarcanes, No. 1, Punjab Canes. *Mem. Dept. Agr. Ind., Bot. Ser.* VII, 1, May, 1915.

The present contribution to the study of sugarcane seedlings in India is divided into four sections, and it has been found convenient to intercalate summaries of the work in various directions carried out on the Cane-breeding Station during its first three years. The first section deals with the material available, and contains an enumeration of the seedlings thus far raised, with notes as to the chief difficulties encountered and the means by which these have been overcome. The second discusses the differences noted in the youthful characters of the seedlings before planting out and at maturity. The next section treats of the mode of analysis adopted and the variations in the juice of the seedlings as regards sucrose content, and the last summarizes the correlations thus far studied between the characters of mature seedlings and the amount of sucrose in the juice. Because of the introduction of results of smaller detached pieces of work at various points in the course of the narrative, it has been considered advisable to append a summary of these at the end of the paper. This summary is not intended to be exhaustive, but deals chiefly with minor matters which might otherwise be lost sight of. I wish to record the fact that I have been greatly helped throughout by the enthusiasm of various members of my staff, and that the carrying out of much of the work described has fallen to their lot. I would especially mention my indebtedness to my First Assistant, M. R. Ry.. T. S. Venkataraman, who has, throughout, helped me with observations, criticisms and willing work, and to Fieldman R. Thomas to whom has been entrusted the delicate work of marking down and bagging the arrows, and raising the seedlings until they were fit for planting in the field. The latter has also greatly assisted me in my observations on the variations in young seedlings. The chemical analyses, other than those done by Dr. Harrison's assistants, are the work of my Chemical Assistant, M. R. Ry., K. Krishnamurti Rao.

ENUMERATION OF SEEDLINGS.

1. Period 1911-13.

Cultivation of the sugarcane in India is extremely ancient, and in many parts of the country it has laid a firm hold on the time-honoured rotation of crops. But this cultivation has not been progressive of late years, partly no doubt owing to the fact that the *jaggery* or *gur* which is its object is not exported to any considerable extent. The Indian *gur* market is self-contained and therefore unaffected by the wave of progress which has lately swept over agriculture in the tropics. But with regard to *sugar*, the matter is very different for, while in former times India took a prominent part in the manufacture and export of this substance, the local production has not kept pace with that in other countries and, in fact, sugar manufacture in India is a negligible quantity, and increasing supplies are introduced every year to meet the growing needs of the people. The Government of India has recently devoted marked attention to this matter and, as there appears to be no intrinsic reason why India should not produce its own sugar, work has commenced in the Agricultural Department on this staple in two directions. In the first place, the local methods of manufacture need revision and, in the second, the class of canes grown is of very poor quality. The latter subject having been exhaustively discussed at the Meeting of the Board of Agriculture held at Pusa in November 1911, it was decided to found a cane-breeding station whose main line of work was to determine the possibility of raising cane seedlings, and thereby to introduce new and improved varieties suitable to the local conditions of the country. This station has been located at Coimbatore in the Madras Presidency, where the canes are known to flower profusely year by year. It was opened in April 1913, but a certain amount of preliminary work was first done in the Botanic Garden attached to the local Agricultural College.

In the first seed pans laid down in the garden, many apparent cane seedlings turned out to be of those of common grasses whose seed had accidentally crept in but, early in 1912, some fourteen were obtained which proved to be seedlings of local varieties of sugarcane. The question as to whether sugarcane seedlings could be raised in India, about which there had been considerable doubt, was thus satisfactorily solved. But this meagre result, after sowing many seed

pans, led to a detailed study of the cane inflorescences. These were carefully examined for ripe seed without success. It was noted, however, that in many of the flowers the stamens were poorly developed and the anthers unopened, while inside their locules there was a mass of undeveloped pollen mother cells. In Java the method of determining whether sugarcane pollen is fully formed (and presumably fertile) has been to test it with iodine solution for the occurrence of starch. The presence of this substance indicates that the pollen grains are healthy, and a blue coloration by iodine therefore shows that the pollen is useful for fertilization. An examination of the pollen grains in the unopened locules at Coimbatore showed absence of starch, while those emerging from split locules were found to be full of this substance. The Java method was therefore replaced by the simpler observation as to whether the anther locules were open for, in that case, fully matured pollen grains were found to be invariably present, and by this means the percentage of fertile stamens in any inflorescence could easily be determined. Judging from the analogy of the inflorescence of the pepper vine (*Piper nigrum*),[1] it was thought possible that, although abundant pollen was to be found in the arrows of other canes in the same field, it was of first importance for the production of seed that good pollen and receptive stigmas should be found side by side in the same flower. The arrival of a set of arrows of a cane growing at Bangalore, in March 1912, with plenty of good pollen, was made a test case and all the arrows available of this variety were immediately sown, with the result that a further lot of 32 seedlings was readily obtained (*cf.* Plate II).

In later work, the stamens of all cane inflorescences have been examined in the following manner. The stamens are shaken out on to a clean piece of paper and preserved in a small envelope. 200 of them are taken and passed rapidly under a dissecting lens and divided into three classes :— Opened, closed, distorted. It has been found that, as in the pepper, if the anthers do not open at the time when the flowers mature, they remain permanently closed under all conditions and, once opened, they remain so permanently. They can thus be examined at any time. The percentage of open anthers in each inflorescence dealt with is entered in the following tables wherever it was obtainable. The failure of previous sporadic attempts at raising cane seedlings in India can be readily explained, in that the state of the anthers was not observed. Almost all such attempts appear to have been made in Northern India and

[1] Barber, C. A. "The Varieties of Cultivated Pepper." *Dept. Agr., Madras*, Vol. III, *Bull.* 56, 1906.

1. Cheni.

2. *Saccharum spontaneum.*

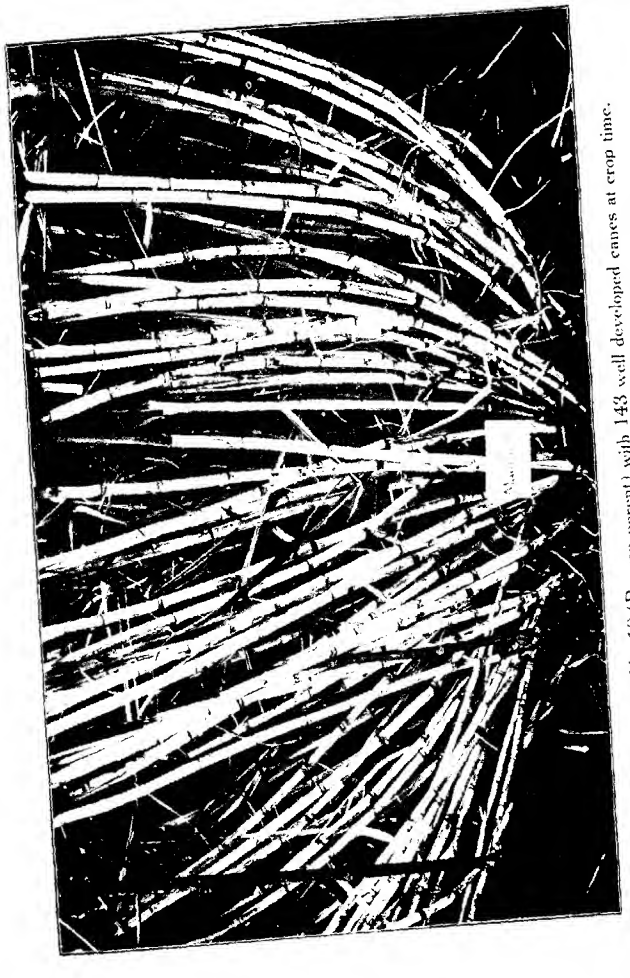
3. Vellai.

4. Red Mauritius.

Illustrating Dehiscence of Sugarcane Anthers.

In all except Vellai the anther locules are opened. In Vellai they are, as usual, closed.
Magnified ten times.

PLATE III.



Madras Seedling No. 10 (Poovan parent) with 143 well developed canes at crop time.

although certain canes in this tract appear habitually to flower, an examination of the inflorescences of indigenous canes, received from North India, has shown that the anthers are completely closed and the pollen is undeveloped (Woodhouse notes that in *Khelia* grown at Sabour the anthers dehisce).[1], [2].

The following is the list of the cane seedlings obtained during the first season :—*Poovan* 9, *Namam* 2, *Kaludai Boothan* 2, *Vellai* 1, all of these being local Coimbatore canes ; *Cheni* from Bangalore 32, in all 46. The first seedlings were obtained from arrows collected in January 1912, and the poor result is now further explained in the lateness of this date in the flowering season, it being established that October-November is the best time for obtaining seed at Coimbatore, and that the fertility of the arrows steadily decreases as the season advances.

As other land was not available, these seedlings were planted out in the Botanic Garden. The ground was entirely unsuited for sugarcane growth and, accordingly, large pits, three feet cubed, were dug and filled with soil and manure ; irrigation was however only obtainable from a well of brackish water. While some of the *Cheni* seedlings suffered considerably from the salt water, most of the seedlings grew enormously under this treatment, and produced a very large number of shoots, one *Poovan* seedling having at crop time, eighteen months from sowing the seed, no less than 143 matured canes (Pl. III). But the juice of these seedlings turned out to be of quality very inferior to that of their supposed parents, and considerable doubt has been raised from this and other facts whether the parentage, other than in *Cheni*, has been correctly stated. Most of the seedlings, in fact, differed considerably from those obtained from the same canes in succeeding years.

A detailed study was made of each seedling, and photographs were taken at various stages of development ; two were sacrificed and dissected in early stages of growth. After the harvest, when the juice was analysed, they were all planted again, and have been grown on each year, in order to test the permanence of their morphological characters and the quality of their juice. At present, in October 1915, there are 38 still surviving. As noted above, the sugarcane commences to flower at Coimbatore in October, and most of the seedlings are obtained during the following two months. They are planted out in the field when about six months old and are ready for harvesting and analysis after another twelve months, or eighteen months from sowing. It

[1] Woodhouse and Basu. The Distinguishing Characters of Sugarcanes cultivated at Sabour, *Mem. Dept., Agr. Ind., Botanical Series*, VII, 2, Apl. 1915.

[2] A large number of arrows were received from North India in 1915, and in these occasionally a few (1—4%) of the anthers were open, April 1916.

has been found convenient to designate the seedlings obtained during any particular season by the years of sowing and of final chemical analysis and, accordingly, the first year's seedlings are called those of 1911-13. Notes as to the character of their juice will be found in a following section.

2. Period 1912-14.

The Cane-breeding Station was sanctioned in October 1912 and a full-time officer placed in charge of it, with a suitable establishment. Profiting by the previous year's experience, it was found possible to raise a comparatively large number of seedlings in the season then commencing, more in fact than could be dealt with at maturity. Of the 10,000 to 20,000 seedlings obtained, some 2,000 were selected, from as many different parents as possible, and grown on. These were raised in the Botanic Garden, but they were planted out in the newly acquired farm at Chettipalayam, a village about a mile and a half from the College. Besides searching the neighbouring country for varieties of flowering canes with open anthers, arrows were obtained from various parts of the Madras Presidency, as well as, through the kindness of Dr. Coleman from Bangalore, as this place has also proved to be an excellent centre for cane-flowering.

A careful note has been taken of canes flowering in recent tours through sugarcane tracts. Taking India as a whole, the flowering of the sugarcane appears to decrease as we proceed north-west. In Madras and Mysore it is a common occurrence, but in the former it is more abundant in the drier, western than in the moister, eastern parts. Flowering is not uncommon among the canes growing at Nagpur, Jubbulpore and other parts of the Central Provinces, and extends in a north easterly direction as far as Assam, but with a diminishing intensity. In Bihar, certain kinds such as *Khari* (and the introduced *Saretha*) flower habitually, and in certain years large stretches of canes have been noted as flowering in the eastern parts of the United Provinces. Passing thence to the north west, however, cane flowering becomes rare or entirely ceases. The following varieties have been noted by Mr. Woodhouse[1] as flowering in exceptional years at Sabour in Bihar :—*Chynia, Khelia, Maneria, Paisahi* and *Shakarchynia*. A large number of the varieties of North Indian canes collected on the Cane-breeding Station at Coimbatore have now flowered, often without the anthers being open.

Note.—It is of some interest to compare, with this brief statement, the flowering of the wild Saccharums observed during the last few years. *Saccharum spontaneum* is widely distri-

[1] Woodhouse and Basu. The Distinguishing Characters of Sugarcanes cultivated at Sabour, *Mem. Dept. Agr. Ind., Botanical Series*, VII, 2, Apl. 1915.

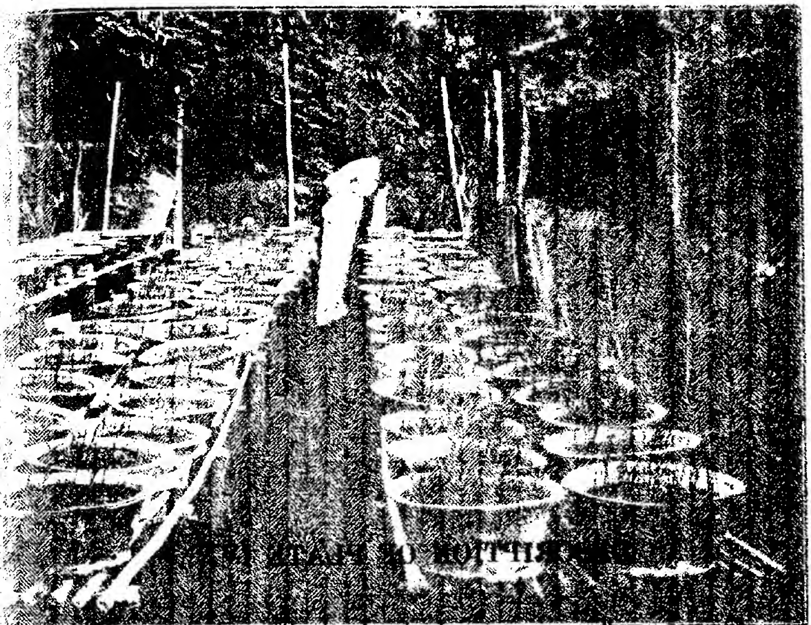
buted over all parts of India and everywhere flowers profusely. It has been successfully crossed with three North Indian canes in the Cane-breeding Station. *Saccharum arundinaceum* appears to be at home in Assam, where it flowers freely, the hill section of the Assam railway revealing a mass of its showy spikes all along its banks. This species probably needs the humid Assam climate for perfection of growth, for it soon becomes rare in a westerly direction. It is recorded as flowering in the Botanic Garden at Saharanpur,[1] but the specimens planted in the grounds of the Lyallpur Agricultural College have not flowered during the eight years since they were introduced. In South India *Saccharum arundinaceum* is frequently planted, and is the usual hedge for *betel* (*Piper Betle*) plantations. It is thus very common at Coimbatore but, although allowed to grow for several years, it has never been known to flower. It flowers, however, in the moister north-eastern part of the Madras Presidency and is reported to have been in flower at Tanjore. *Saccharum Munja* is not much in evidence in Assam and Bengal, if it occurs there but, passing along the submontane tract to the west, it soon replaces *Saccharum arundinaceum* and extends, flowering profusely, from Bihar to the Punjab. It has been introduced to the Cane-breeding Station and grows and flowers fairly freely, but the flowers are poor and nothing like so handsome as in the north. The stamens are, however, fairly well developed. *Saccharum Narenga* is, again, at home in Assam, where vast tracts on the northern side of the Brahmaputra and the Shillong hills are covered by it, often to the exclusion of other vegetation. It appears to pass along the foot of the Himalayas to the north-west. A chance arrow collected in North Bihar has given many seedlings in the Cane-breeding Station, and it grows and flowers freely there with fully developed stamens. It has been successfully crossed with *Vellai*, a thick introduced cane. In conclusion, there seems to be a certain amount of confusion in the classification of Indian Saccharums. In the *Flora of British India*, *Saccharum Munja* and *S. arundinaceum* are placed together under the latter specific name. This arrangement is followed in the Calcutta Herbarium. From my knowledge of the growth of these plants and their divergent distribution, I cannot but feel that they are entirely separate, but this conclusion is chiefly based on their leaf and stem characters. In a recent tour in Assam and Bengal, I have, moreover, come across a number of puzzling forms which lead me to suspect that still other wild Saccharums may occur there as yet unseparated or undescribed. None of them were, however, in flower at the time of my visit.

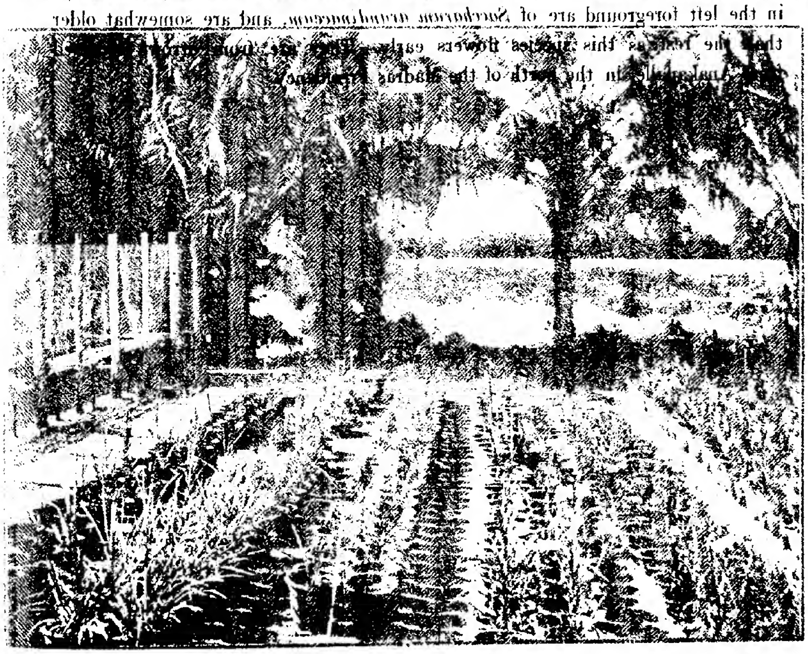
As many of the seed pans during the 1912-14 period also showed a good growth of various grasses, the whole question of the early treatment of seedlings was overhauled and a great number of methods were tried, both as to the most suitable medium in which to grow them (from sand, red and black earth, leaf-mould, manure, to pounded peat from the Nilgiris and various mixtures of these substances) and the manner in which the medium should be treated, so as to destroy any grass or weed seeds that they might contain. The following is the method (copied from Java) in use at the time of writing. Old horse manure is obtained, finely pounded, watered and exposed to the air. All seeds in it soon germinate and are pulled out as they appear, and, after a time, the manure, cleared of its weeds, is stored in pits for further use. The arrows are collected when the first florets begin to fall or are blown off by the wind, and are kept in paper packages for a week or ten days for the seeds to mature,

[1] Hole. On Some Indian Forest Grasses and their Ecology. *Indian Forest Memoirs, For. Bot. Ser.* I, 1, 1911. Pl. XXII.

after which they are ready for sowing. Equal parts of the prepared horse manure and river sand are well mixed and placed in shallow pans, 12″ across and 3″ deep. The fluffy inflorescence of the cane is broken up and plastered upon the surface of the mixture in the pan and thoroughly watered through a rose watering can. After this it is found that the flowers and flower stalks form a welted mass disturbed neither by wind nor by heavy rain. It was sought at first to protect the young seedlings from the torrential rains which fall at this time of the year (October-November), but it was soon found that, owing to the porous nature of the mixture of sand and horse dung, they suffered not the slightest injury. It was found, however, essential to keep them fully exposed so as to have as much sunlight as possible, as the least shade rendered them liable to damping off or yellowing. In this manner, if there is any seed in the arrows, it is usual to look with a lens for the first spot of green in the germinating embryo within three or four days. But experience has shown us that sometimes the seed does not germinate so quickly, the seed in some pans continuing to germinate for a month after sowing. When the seedlings grow thickly, it is advisable to prick them out at greater distances in similar pans in which a certain quantity of soil and leaf-mould is added, and this is done when they are about two inches high. Where, however, there is plenty of room, they are left in the pans until they are some three to six inches high, as each transfer appears to check their growth. They are then transferred to pots (*cf.* Pl. IV). The soil in these is carefully prepared as follows. Fine red earth is brought from certain fields about seven miles away, and this is mixed with equal parts of ordinary earth, cattle manure and leaf-mould. The pots are 9″ across and a foot high and one seedling is placed in each. They are left in these pots until they are planted out in the field. Watering in both the pans and the pots is a considerable item of expense and needs constant care. The pans are, in the absence of rain, watered with a can five times a day, and the pots should be watered twice daily. Improvements are constantly being made in this matter, but one of the latest is to dig broad trenches in which half a dozen rows of pots may be sunk and where they may be irrigated all together. The sides of the sunk pots are protected from the air and, when thus arranged, they need not be irrigated more than, say, twice a week, and the cost of the operation is nominal. This, with five thousand pots, is a matter of considerable saving of expense. But there are drawbacks in this method which will be referred to when the further treatment of the seedling is described (*cf.* p. 149).

One of the greatest obstacles in the raising of the seedlings at Coimbatore is the fact that the canes arrow during the north-east monsoon, at a time when





DESCRIPTION OF PLATE IV.

Sugarcane seedlings in pans and pots. In the latter, the larger seedlings in the left foreground are of *Saccharum arundinaceum*, and are somewhat older than the rest as this species flowers early. They are from arrows received from Anakapalle, in the north of the Madras Presidency.

PLATE IV.

Madras Seedling No. 1017, arrowing.

Method of selfing or crossing arrows. Crosses are effected by blowing in pollen each day and immediately covering up again.

two-thirds of the annual rainfall descends. These rains are often heavy and accompanied by strong winds, so that many arrows are broken or the pollen is destroyed by thorough wetting. Sometimes, for a week or fortnight on end, no collecting can be done, and this, considering the short time during which fertile arrows can be obtained, is a serious disadvantage. Many of the arrows during the earlier years were obtained at places from five to ten miles from the farm, and in order to ensure their daily inspection and bring the matured arrows in safely, a great deal of travelling under trying conditions was necessary.

The protection of the flowers from cross-pollination was instituted during the 1912 season, but it was found impossible properly to supervise the distant cages, and this supervision was only effective in cages over the few arrows in the Botanic Garden. The cages are made of iron rods or, preferably, strips of bamboo covered with fine, close muslin, as the pollen is capable of passing through the finest meshes. They hang over the inflorescences from a tall gallows-like support, and can be raised or lowered at will. The whole apparatus is a close adaptation of that used in the Java cane-breeding work (Pl. V). Because of heavy winds, it has often been found necessary to place an additional upright bamboo or even two and tie the swinging cage to them. The operation requires considerable care, because it has been found that even the slightest permanent bend of the long, fragile inflorescence stalk destroys the fertility of the whole arrow, and this is by no means an infrequent occurrence in the heavy weather at Coimbatore at this time of year. From past experience, a general impression has been gathered that the very fact of caging is prejudicial to the full development of the inflorescence, although large numbers of seedlings are sometimes obtained in this way. Caging must be done before the arrow emerges from its enveloping sheath, for the stamens have been found sometimes to open before this emergence occurs. Enclosing the inflorescence thus takes place some time before the introduction of foreign pollen. The cane varieties are closely watched about this time of year and the approach of flowering is foretold some time before it occurs by the elongation of the terminal internodes and the presence of small leaves at the top of a cane shoot. The cane is then said to be in " short-blade " and its record is carefully gone over to see in what way the inflorescence may be used. If, on emergence, the flowers are found to contain few or no open anthers, crossing may be attempted, but we have at present no criterion by which to tell whether the female organs are fully formed, as we have in the male. Our only guide is the successful rearing of the seedlings in the pan after sowing. To illustrate the need for daily inspection of the cages, one fact may be mentioned here. On several

occasions it has been noticed that rats have gained access to the cages, have pulled together the fluffy inflorescence to form a nest, and have even introduced pieces of foreign arrows into the cages—an undesired attempt at cross-pollination on their part! Half-inch wire netting has to be added when rats are abundant.

In the following table a summary is arranged, showing the origin and fate of the seedlings raised during the period 1912-14, with notes on the percentage of open anthers, and on the possible male parentage of the seedlings, where the flowers were unprotected from foreign pollination. It may be noted that comparatively few of the inflorescences were protected, and that then only the female parent is known with certainty: batches of seedlings from unprotected arrows are termed "General Collection," as contrasted with "Crossed" or "Selfed" lots.

A study of the contents of the table brings to light certain interesting facts regarding the germinating power and vitality of the different classes of seedlings. The local canes grown by ryots round Coimbatore are five in number, and these produced the great bulk of the seedlings of the period. These are thick (probably exotic ?) canes which have been established for a number of years:—*Chittan, Karun, Kaludai Boothan, Poovan* and *Vellai*. From their detailed morphological study, it seems probable that the first three are closely related to one another, there being some ground for supposing that *Chittan*, a striped cane, is the oldest and that *Karun* (claret) and *Kaludai Boothan* (green with blush of pink) have at some time arisen as sports from it. *Karun* and *Chittan* produced a large number of seedlings. They are hardy canes of moderate value, and, in the absence of the better ones, a good number of their seedlings were planted out. *Kaludai Boothan*, on the other hand, was disappointing in germination (although it is interesting to note that in the succeeding year matters were reversed) and, further, its seedlings were unfortunate in that they were planted out in inferior land. *Poovan* is a glaucous green cane with rather poor juice, much appreciated as an eating cane, and is fairly widely cultivated. It proved difficult to raise seedlings from it and they were different in character from those obtained in the first year, thus supporting the idea that the latter were in some way abnormal. No seedlings were obtained from *Vellai* arrows. This is by far the best local cane but, as will be seen later, the development of pollen is very precarious (*cf.* also Pl. II). *Naanal*, although a South Indian cane, is not grown near Coimbatore and is very different from the rest. It appears to be an indigenous or *desi* cane somewhat similar to the *Chin* group, although a good deal thicker than most of them, is very hardy and has fair juice. The arrows were obtained from

Variety	Locality	Anthesis. % open	Pans sown	Germination	Planted out	Serial Numbers	Analysed harvest	Selected*	Remarks as to probable Parentage	
Karun ...	Villages round Coimbatore.	42 %?	55	3944	504	819—1322	397	75	Anthesis determined from an old arrow, therefore probably too low—Selfed or possibly crossed by neighbouring Kaludai Boothan or Chittan.	These varieties are usually grown intermingled in the fields.
Kaludai Boothan.	Do	71 %	11	714	264	1520—1783	61	8	Selfed or possibly crossed by neighbouring Karun or Chittan.	
Chittan ...	Do	76—78 %	23+	2761	769	50—818	509	75	Selfed or possibly crossed by neighbouring Kaludai Boothan or Karun.	
Poovan ...	Do	75 %	Sown in bed.	50	27	1785—1811	14	4	Poovan flowers at a slightly different time from other local canes (above)—Probably selfed, as no other arrows noted at the time in the fields.	
Naanal ...	Karur, in Coimbatore district.	2·5 %?	23+	267	197	1323—1519	149	18	Naanal is usually grown pure in the fields and the other local varieties (above) were not present. The arrows were collected at Karur some distance away and most stamens dropped in transit: of those remaining 2·5 % were open. From a study of the seedlings it is possible that crosses with a wild Saccharum occur.	
Cheni ...	Mysore ...	9—10 %?	16	50	36	2082—2117	15	6	Cheni is usually grown pure in Mysore. Only old stamens were available, therefore percentage open probably too low. Chances of a cross remote.	
Java ...	Do	43—48 %	6	3000	17	1919—1935	2	1	Old arrows gave 43-48% open anthers, a figure probably too low because the first flowers usually have more open anthers. Selfed or possibly crossed by B208 or Pattapatti.	
B208 ...	Do	2·5—87 %	19+	52	40	1936—1975	7	3	Little information available. Only old flowers available. No information as to other arrows near.	
Seema-like Mauritius.	Samalkota, Madras Pres.	66 %	4	35	27	1892—1918	3	0	No information regarding arrows in the field. Received by post.	
Saretha ...	Botanic garden, Coimbatore.	86—98 %	3	166	80	1812—1891	51	25	Muslin-bagged, therefore selfed. All from one arrow.	
Chin ...	Do	40 %?	1	3	3	1976—1978	3	2	Upper stamens 40 % open anthers, lower twisted and distorted. Perhaps selfed as no other arrows very near, but *Saccharum spontaneum* flowering. Seedlings remarkably like the next lot.	
Chin × *Saccharum spontaneum*	Do Do	0 % 95 %	4	22	18	1980—1997	13	9	Chin anthers closed. Muslin-bagged previous to emergence and afterwards dusted daily for six days with *Saccharum spontaneum* pollen. Apparently a genuine cross.	
Shakarchynia. × *Saccharum spontaneum.*	Do Do	0 % 95 %	2	89	84	1998—2081	75	64	As above. Apparently a genuine cross.	
Totals...	.....	.....	167	11153	2032	50—2081	1299	290	Besides the above series a large number of seedlings were raised from *Saccharum spontaneum* and *Saccharum Narenga*.	

* The selection was for high sucrose content or botanical interest. The former applies to the thick canes, the latter to the indigenous varieties—Naanal, Cheni, Saretha, Chin, and the crosses.

Karur, some fifty miles distant, and there is reason to suppose that some of the seedlings were abnormal. Seven of them showed marked resemblance to *Saccharum spontaneum* and are spoken of as the "spontaneum class" of *Naanal* seedlings.

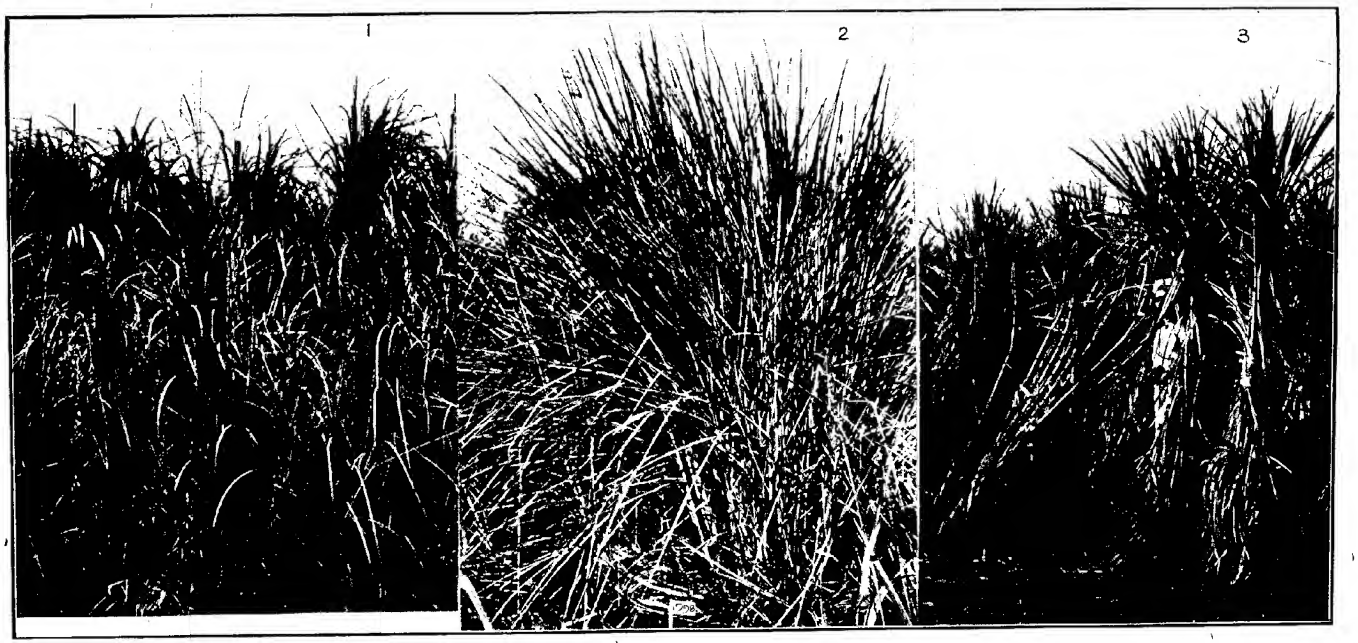
Of the arrows obtained from Bangalore, "*Java*," a valuable cane of unknown origin, produced an enormous number of seedlings, an average of at least 500 per pan. But, in spite of the greatest attention, including special treatment and early pricking out, the seedlings soon turned brownish yellow and died in great numbers. This delicacy continued after potting up and, of the whole lot of over 3,000 seedlings, it was only possible to place 16 in pots and to grow two to maturity so that they could be analysed. The results of the sowing of *B. 208* arrows, from which much was expected was, on the other hand, disappointing because of the poor germination, added to great mortality when planted out. *Cheni*, an indigenous Mysore cane, somewhat resembling *Naanal*, also gave a poor result.

Seedlings raised in the Botanic Garden, from indigenous North-Indian canes introduced in the previous year, had both parents known. *Saretha* was selfed and gave good results. It is a valuable cane in its tract (Meerut and Aligarh) and is a constant flowerer. The crosses between *Chin* and *Shakarchynia* and the wild *Saccharum spontaneum* were also healthy and vigorous throughout their growth. It was unfortunate that crosses could not be effected between these North Indian canes and the thicker, exotic ones, but they did not flower at the same time. The pollen in *Chin* and *Shakarchynia* was undeveloped, and the crosses effected had their use, in that the perfect fertility between *Saccharum spontaneum* and cultivated canes was demonstrated, and the character of seedlings with *Saccharum spontaneum* parentage was established (Pl. VI).

All the seedlings obtained during this season were carefully studied at crop time, according to a detailed plan left behind by the author when going on leave, and, as will be seen in the last section, these descriptions form the basis of the correlations studied between the morphological characters of the seedlings and the quality of their juice.

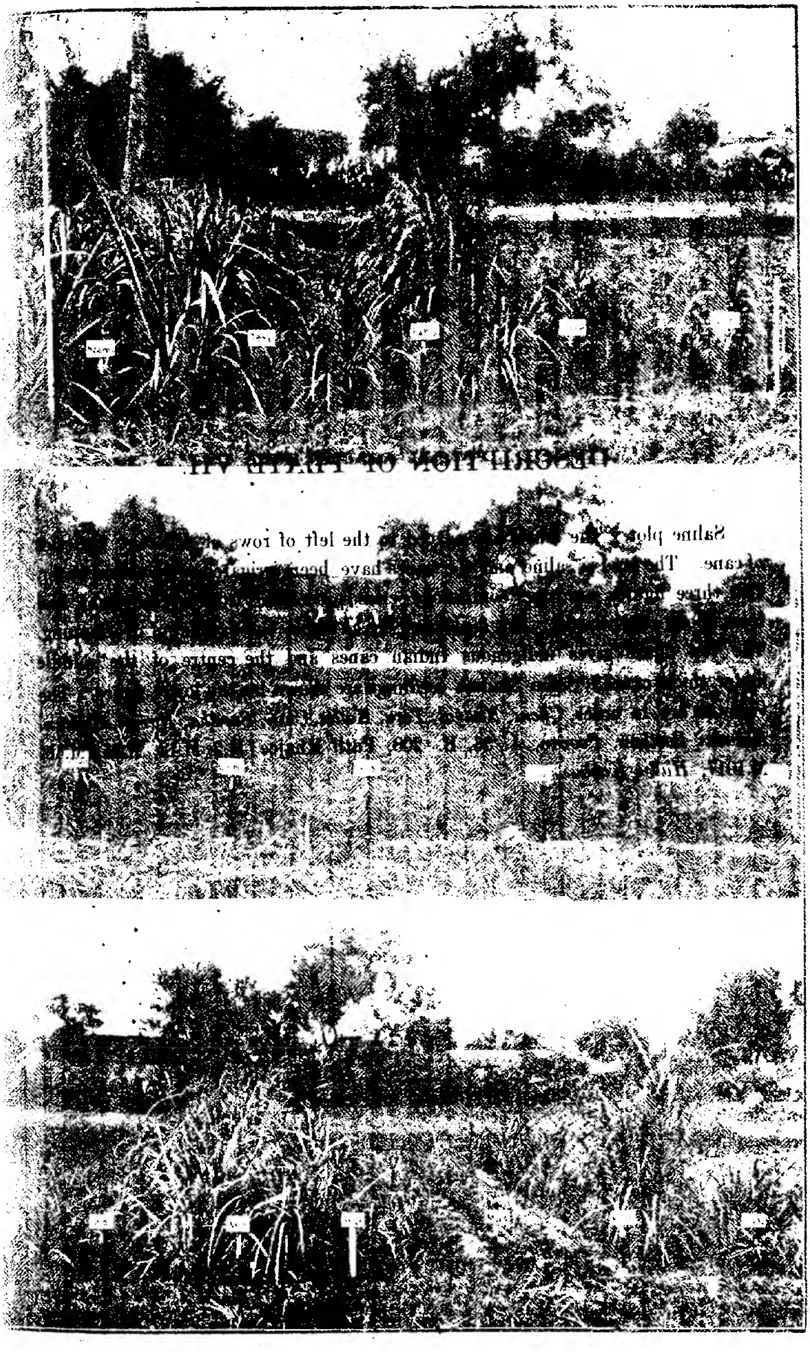
3. Period 1913-15.

The canes growing on the newly founded Cane-breeding Station, planted about May, did not flower to any great extent at the end of 1913, and outside arrows were again chiefly used to obtain seedlings during this season. Great help was, however, afforded by a free flowering of the canes growing in the wet



Shakarchynia x *Saccharum spontaneum*. Fig. 1. *Saccharum spontaneum* in the foreground, with extremely narrow leaves, curving gracefully. Fig. 3. Shakarchynia, the female parent, a Bihar cane with strict, erect-tipped leaves. Fig. 1. (background) and Fig. 2. seedlings obtained by crossing these two. In the former the leaftips are curved like those of *Saccharum spontaneum*, and in the latter they are erect and strict, as in Shakarchynia.

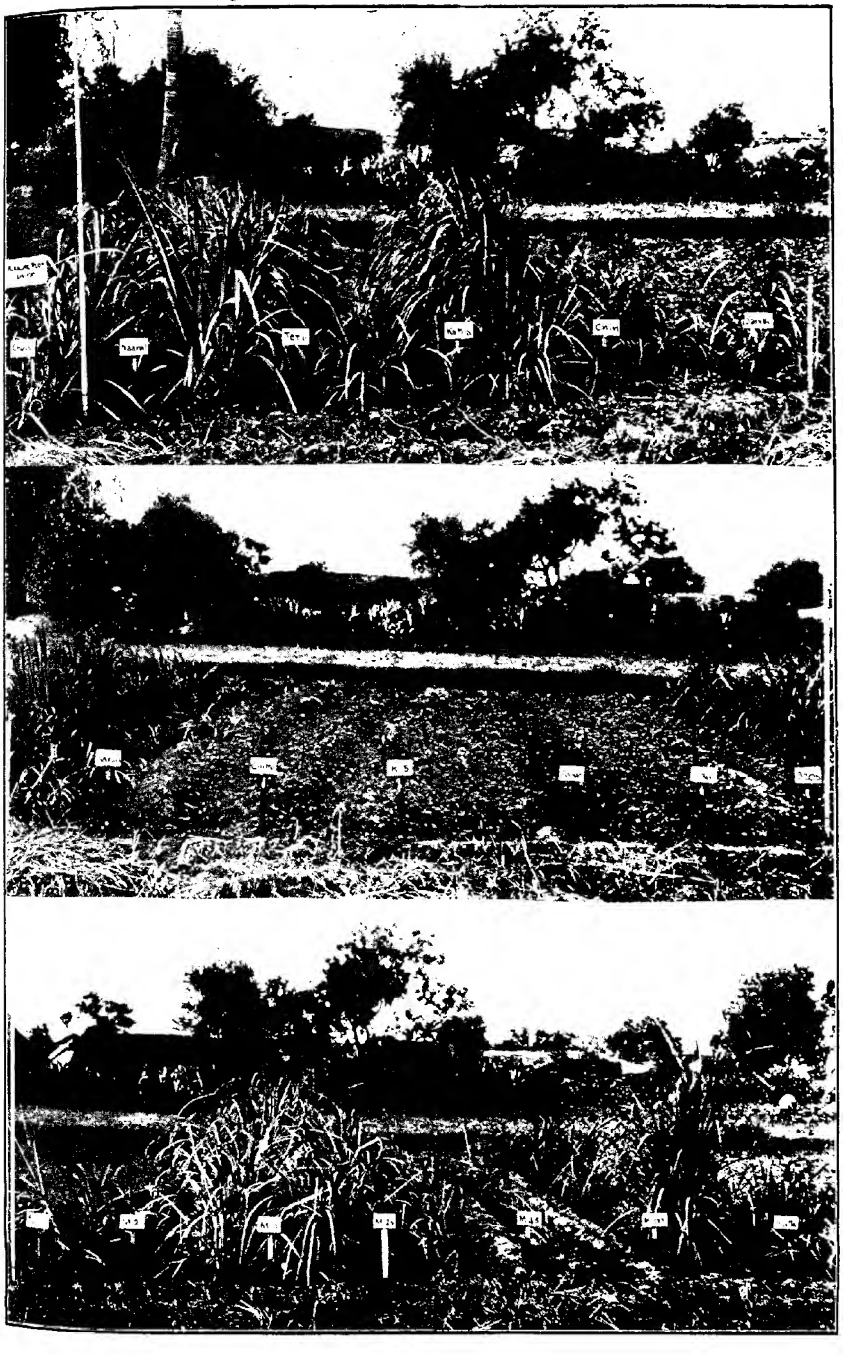
PLATE VI.



DESCRIPTION OF PLATE VII.

Saline plot. The labels are placed to the left of rows of different varieties of cane. The land is saline and the canes have been irrigated with saline water. The three figures are one continuous series, proceeding from left to right and from above downwards. The measuring sticks show the extent of overlapping. The top figure gives indigenous Indian canes and the centre of the middle figure thick canes. Some Madras seedlings are shown in the lower figure. The varieties are, in order, *Cheni*, *Naaṇal*, *Teru*, *Katha*, *Chin*, *Saretha*, *Karuṇ*, *Chittan*, *Kaludai Boothan*, *Poovan*, J. 36, B. 208, Putli Khajee M.2, M.12, M.25, M.45, M.1017, *Hullu*, *Kabbu*.

PLATE VII.



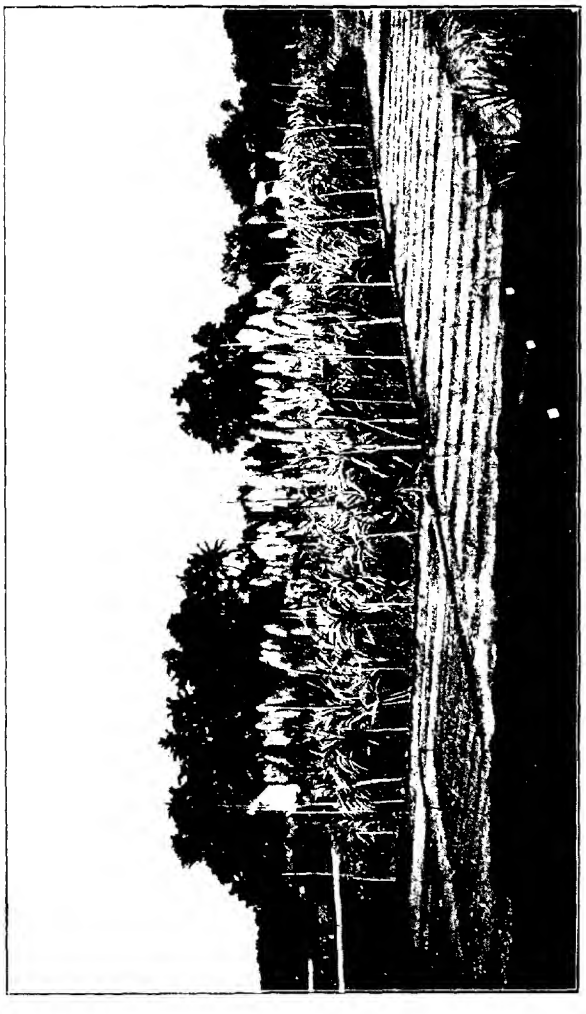
(tank-irrigated) land on the Central Farm near by. The villages around were again ransacked, arrows were forwarded by post from the Madras Farms at Samalkota and Taliparamba, and, as in the previous season, a large number were obtained from Bangalore. Over 20,000 seedlings were raised and, from these, some 2,400 were selected and planted out. A considerable number of varieties of canes had meantime been collected from various parts of India and these formed the "varietal plots" in the Cane-breeding Station. But their growth was at first extremely poor, and few if any of them showed any tendency to form arrows. This led to a study of the reasons for their failure, as it appeared to be almost as difficult to grow North Indian canes at Coimbatore as to reverse the process and grow thick canes in the fields in North India.

The piece of land selected for the Cane-breeding Station was a block of "garden land" (well irrigated), within easy reach of the College laboratory. The more usual cane land, black clay, irrigated by water from tanks and termed "wet-land," was avoided, as it was considered unsuitable for the growth of seedlings intended for North India. Upon examination, the soil on the farm was found to be slightly saline, and it was recognised before purchase that it would need a certain amount of treatment before sugarcanes would grow there normally. Isolated plots of canes were seen growing near, and the ryots agreed that it was suitable land, but pointed out, in their homely language, that "it was not yet accustomed" to sugarcane. This of course did not interfere with the excellent growth of the seedlings, for these were planted in pits with specially prepared earth and manure. An analysis of the wells on the station showed that five of them had brackish water and irrigation had therefore to be confined to the one sweet-water well, on which a pump and oil engine were erected capable of dealing with the four or five acres intended for sugarcane cultivation each year. The cause of the poor growth of the varieties planted during the first year was not far to seek, in that they were planted out of season and, of necessity, on land which had been irrigated for years by brackish water, and which there was no time to prepare (*cf.* Pl. XXVII for a photograph of canes growing in this land; these were thick canes), and a series of tests were instituted to note the effect of this water on the different varieties of cane introduced. The results of this experiment are extremely interesting, showing that different canes vary enormously in their capacity of resistance to saline soil and water, some growing strongly and rapidly while others die out completely (Pl. VII). The experiment is being continued yearly, as an alkaline or "saline plot," on untreated land irrigated by brackish water, into which the varieties are introduced in turn. The land intended for cane growing in each season is heavily covered with tank silt and a crop of juar

(*Andropogon Sorghum*) planted. A green-dressing plant (usually *Dolichos Lablab*, the field bean), is then planted and dug in, and wide drains are made at short distances apart. This treatment has had very beneficial effects and, although some super-sensitive varieties still appear to suffer, the North Indian canes, at any rate, have now been fully acclimatized and are growing extremely vigorously.

The study of the causes of arrowing in the cane has also led to fruitful results. There are two cane-planting seasons in the neighbourhood of Coimbatore, one in February-March and one in July-August or even later. The former is in vogue on garden land irrigated by wells and the latter on wet lands under tanks. The period for planting in wet lands is limited by the filling of the tanks, but the ryots cultivating garden lands are free to choose their own time. They have selected February-March for several reasons. The canes planted then are still young when the fierce winds of the south-west monsoon sweep over the land in June to August, and are well established and off the ground when the heavy wet weather comes with the north-east monsoon in October-November. Incidentally, they also secure a suitable ripening season for the canes, in the dry cool months of December and January followed by the dry hot months of February and March, the hottest part of the year at Coimbatore. From a special study of each field from which arrows were obtained in the neighbourhood, it soon became evident that canes planted in February-March do not usually flower, while those planted at any time between August and November do so in the following October-November, if allowed to remain in the ground. In the wet land generally, then, the canes are more likely to flower, and this has been found to be the case even when they are planted as early as April-May. As a result of this study, an "arrowing plot" was put down on the station as an experiment with certain varieties in November 1913. The result was eminently satisfactory and the plot was a mass of arrows in the following October (Pl. VIII). At the same time, through the kindness of Mr. Wood, a number of North Indian and other cane varieties were planted in the wet land on the Central Farm and most of these also flowered. Altogether, some twelve North Indian canes bore arrows, some of them for the first time on record. Unfortunately, in most of these, the stamens proved to be obstinately closed, but it is hoped that the way is being opened for obtaining the desired cross between a hardy North Indian indigenous cane and a richer exotic one, if they can be induced to flower at the same time.[1]

[1] During the 1915 season, 71 varieties of cane flowered on the Cane-breeding Station, half of which were North Indian canes.



Arrowing plot, October 1914.

Enumeration of 1913-15 *Seedlings.*

1. ONE PARENT KNOWN, OR SELFED.

Variety	Locality	Anthesis, % open	Pans sown	Germination	Planted out	Serial Numbers	Analysed at harvest	Selected *	REMARKS ON PARENTAGE
Karun	Villages round Coimbatore.	40—50 %	41	170	100	2200—2299	44	...	Probably mostly selfed. Practically pure Karun in the field, some arrows caged.
Kaludai Boothan...	Do	80 %	30	3,000	400	2400—2799	121	21	Probably mostly selfed, but possible crosses with Poovan, of which a number of arrows were present.
Chittan ...	Do	80 %	30	120	100	2300—2399	45	5	Probably mostly selfed. The bulk of the field consisted of Chittan, with a sprinkling of Poovan and Kaludai Boothan.
Poovan... ...	Do	90—91 %	10	125	100	3300—3399	16	2	Probably mostly selfed. One lot caged and selfed. Karun was flowering in the field also.
Red Mauritius ...	Central Farm, Coimbatore.	96 %	1	1,000	7	4293—4299	...	...	Caged and selfed.
Green Sport of Striped Mauritius	Do	45 %	16	110	100	4300—4399	45	17	No record of other varieties flowering.
Red Sport of Striped Mauritius.	Do	75 %	8	20	16	4400—4416	13	4	No record of other varieties flowering.
Fiji C.	Do	97·5 %	6	130	81	4418—4498	13	2	The bulk of these were caged and selfed.
Fiji B.	Do	92·5 %	1	10	2	4416—4417	...	...	Caged and selfed.
Ashy Mauritius ...	Central Farm and Mysore.	68—83 %	5	155	100	4500—4599	46	17	50 seedlings caged and selfed | In the fields with these varieties all were flowering near together. The seedlings are selfed or casual crosses.
Striped Mauritius	Do	67—87 %	18	380	200	4000—4199	96	27	100 seedlings caged and selfed |
Java	Mysore ...	46—76 %	15	9,000	400	3400—3799	169	79	
B. 208	Do	67—90 %	14	1,850	200	3800—3999	103	44	
White Mauritius	Do	60—77 %	1	530	93	4200—4292	22	6	One-third caged and selfed. No record regarding other varieties flowering near.
TOTAL ...			196	16,610	1,899	2200—2799 and 3300—4599	733	224	

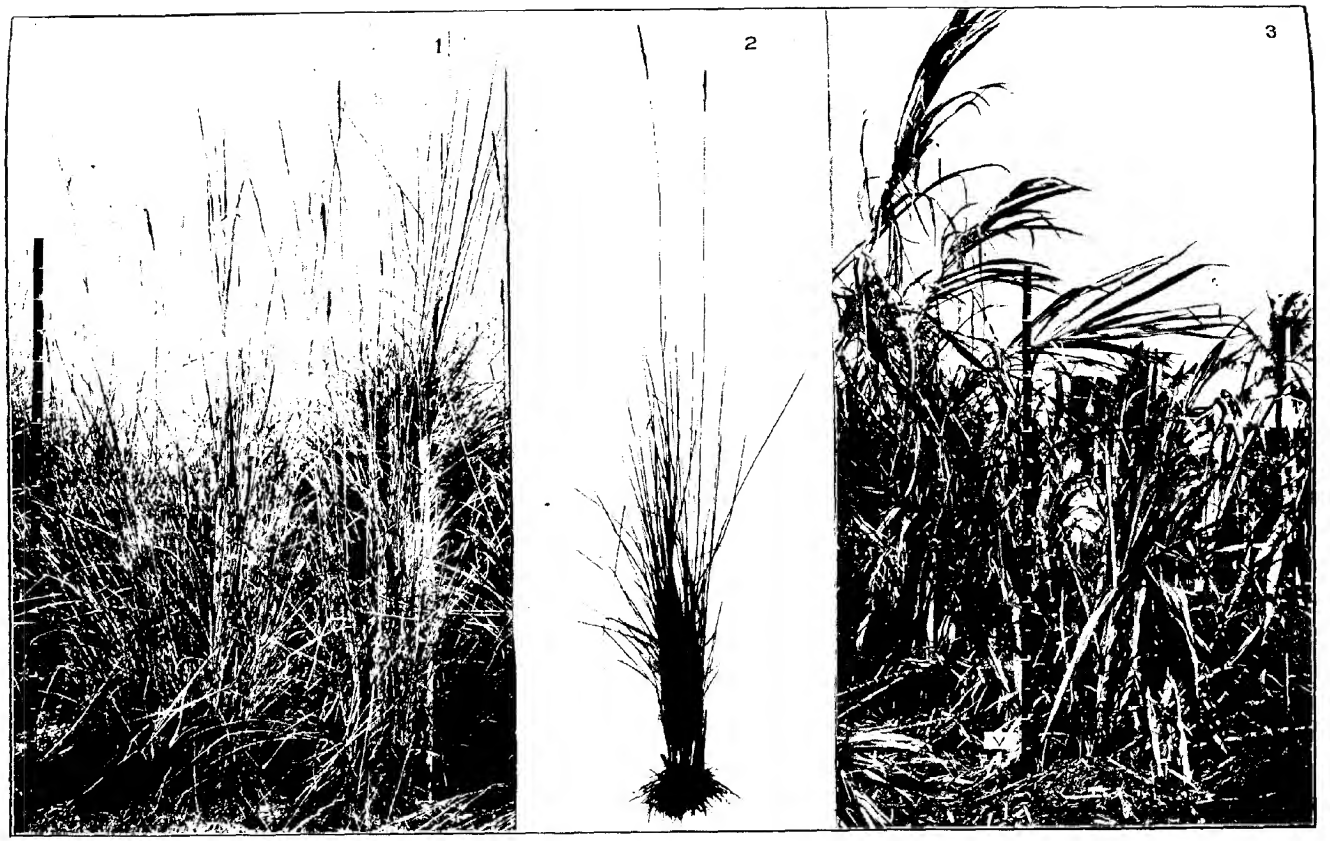
* The standard of selection was raised this year to 18% sucrose in the juice and over, in all excepting Vellai × *Saccharum Narenga* and Vellai × Naanal Seedlings **1464, 1354, 1428.**

Enumeration of 1913-15 *Seedlings.*

2. ATTEMPTED CROSSES.

Varieties crossed	Locality	Anthesis, % open	Pans sown	Germination	Planted out	Serial Numbers	Analysed at harvest	Selected	REMARKS AS TO PARENTAGE
Vellai × ...	Central Farm and villages around.	4—63 %	4	35	16	3200—3215	1	--	Probably crosses among selfed seedlings.
Chittan ♂ ...	Villages round Coimbatore.	80 %							
Vellai × ...	Central Farm	0 %	4	110	95	3100—3194	56	10	Crosses.
Fiji C ♂ ...	Central Farm	60—97 %							
Vellai × ...	Central Farm	1 %	2	40	32	3000—3031	20	8	Probable crosses.
Karun ♂ ...	Villages round Coimbatore.	80 %							
Vellai × ...	Central Farm and villages.	17—50 %	7	150	100	2900—2999	58	16	Probably crosses among selfed seedlings.
Ashy Mauritius ♂ ...	Central Farm	83 %							
Vellai × ...	Central Farm and villages.	4—63 %	4	70	66	3032—3097	33	7	Probably crosses among selfed seedlings.
Striped Mauritius	Central Farm	87 %							
Vellai × ...	Villages round Coimbatore.	?	4	200	100	2800—2899	87	3	Judging by the characters of the seedlings, apparently all crosses.
Sacch. Narenga ♂	Cane-breeding Station.	90 %							
Vellai × ..	Villages round Coimbatore.	5 %	5	20	16	3248—3263	12	1	Judging by the characters of the seedlings, apparently all crosses.
M. 1464 ♂ ...	Cane-breeding Station	93 %							
Vellai × ...	Central Farm	1 %	1	50	32	3216—3247	22	1	Judging by the characters of the seedlings, apparently all crosses.
M. 1354 ♂ ...	Cane-breeding Station.	90 %							
Vellai × .	Central Farm and villages.	3·5 %	3	60	32	3264—3295	18	3	Judging by the characters of the seedlings, apparently all crosses.
M. 1428 ♂ ...	Cane-breeding Station.	97·5 %							
Saretha × *Saccharum spontaneum.*	Cane breeding Station.	0 % 90 %	1	40	30	Not numbered.	23	3	A cross.
TOTAL ...	... ...	...	35	775	519	2800—3295	307	52	

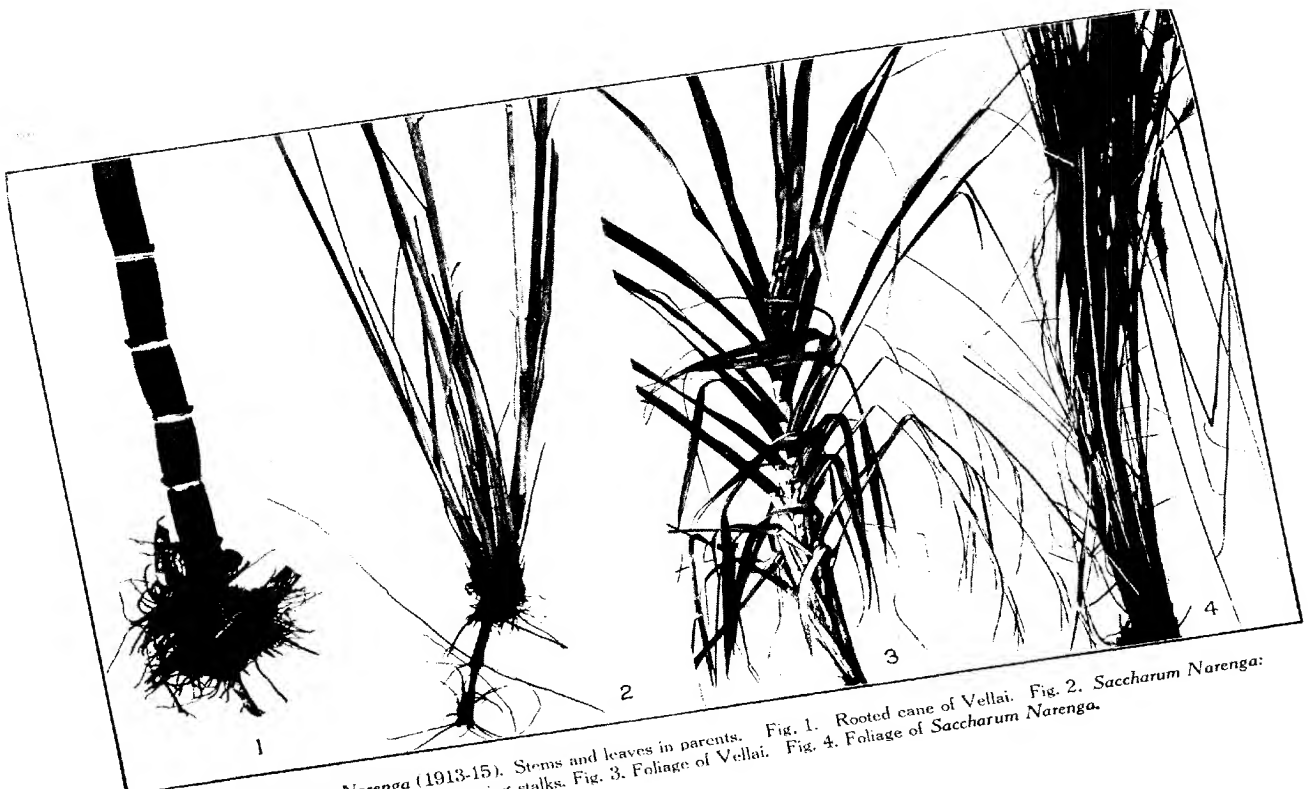
Besides the above, a large number of Madras seedlings with *Saccharum spontaneum* blood in them and the *Saccharum spontaneum* class of Naanal seedlings were selfed and crossed in various ways. About 700 of these were planted out but time was not available for their full study and they were not numbered in the collection.



Vellai x *Saccharum Narenga* (1913-15). Figs. 1 & 2 *Saccharum Narenga*, continuously flowering in the Cane-breeding Station.
Fig. 3. Vellai, a thick Coimbatore cane.

Vellai x *Saccharum Narenga* (1913-15). Crosses obtained. Fig. 4. Young seedlings flowering when 10 months old. Fig. 5. The same plot at crop time. These flowered again when 22 months old.

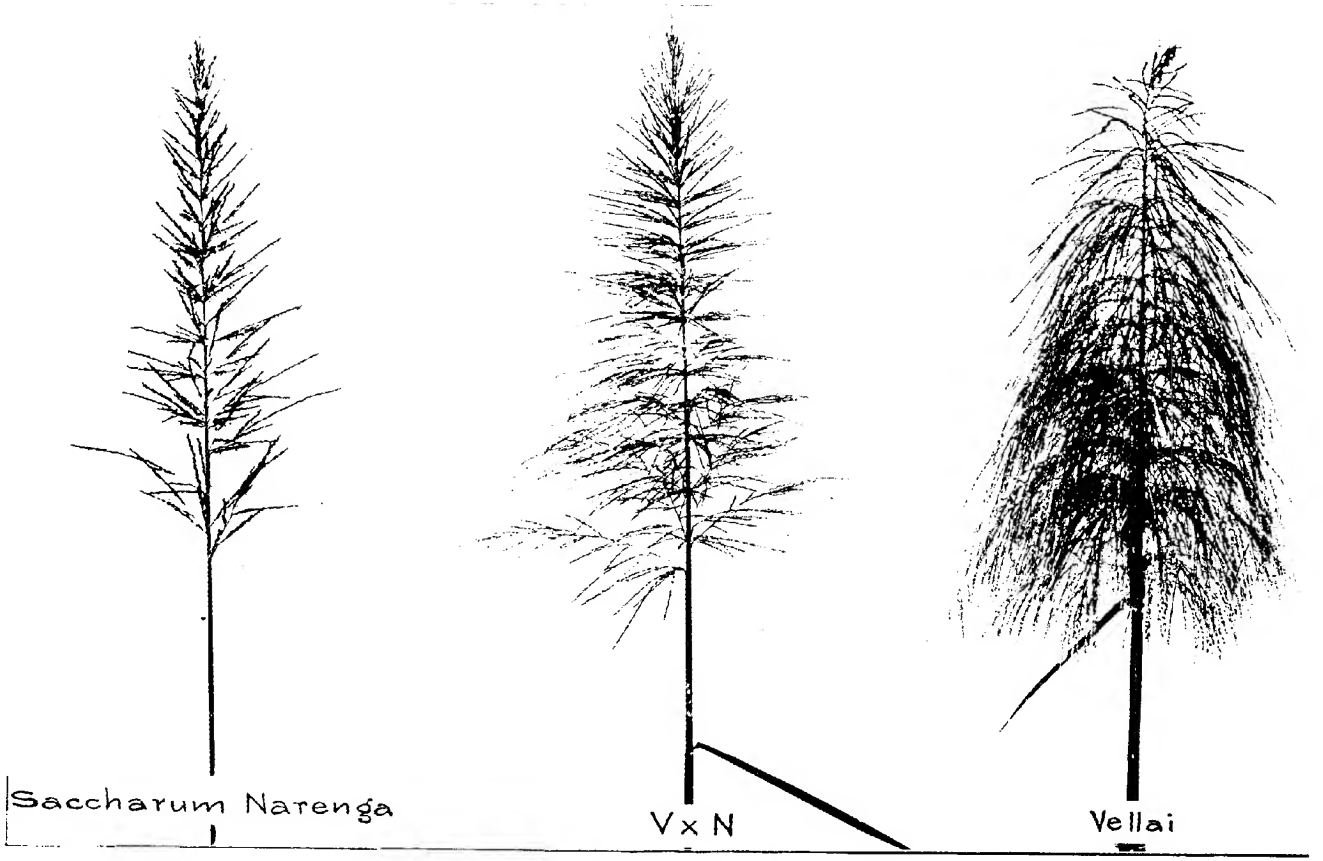
PLATE IX b.



Vellai x *Saccharum Narenga* (1913-15). Stems and leaves in parents. Fig. 1. Rooted cane of Vellai. Fig. 2. *Saccharum Narenga*: all the canes are flowering stalks. Fig. 3. Foliage of Vellai. Fig. 4. Foliage of *Saccharum Narenga*.

Vellai x *Saccharum Narenga* (1913-15). Canes of parents & seedlings. Fig. 5. Two Vellai canes. Figs. 6. *Saccharum Narenga* "canes" Fig. 7. A selection of the canes of the resulting crosses, from the thickest to the thinnest, one average cane from each of six seedlings.

PLATE Xb.



Vellai x *Saccharum Narenga.* Arrows of the parents and of a typical cross.

In the table giving details of the seedlings obtained in 1913-15, several features of interest are observable. In the first place, it may be noted that there is a total absence of seedlings with parentage of indigenous Indian canes. This was by no means of choice but, as has already been pointed out, hardly any of these canes flowered during the year, or being transferred, out of season from the Botanic garden to the Cane-breeding Station. Secondly, there is a greatly extended range of parents, especially in the direction of those of better quality, more recently introduced into India. Thirdly, taking advantage of the fact that *Vellai* frequently has a very poor development of open anthers, a serious attempt was made to dust its arrows with pollen from other varieties, an experiment which was rendered possible by a large number of arrows on the *Vellai* plants growing in the wet land on the Central Farm.

These *Vellai* arrows on examination gave percentages of opened anthers from 0 to 63 (*cf.* Pl. II), and the probable proportion of crosses obtained is judged accordingly in the remarks column. Where the pollinating plant was a thick, exotic cane, it is less easy to state whether crosses have been obtained. Those used were *Chittan*, *Karun*, *Fiji C*, *Ashy Mauritius* and *Striped Mauritius* and all of these canes are more or less similar in general character to *Vellai*. In the cases of *Vellai* pollinated by *Saccharum Narenga* and by Madras Seedlings 1464, 1428 and 1354 (parents *Naanal*), however, there is no manner of doubt, from a casual glance, that all or almost all are genuine crosses. The differences between the parents are very great, and the seedlings obtained are half way in measurements of leaf and stem and in the character of their inflorescences, in general habit and appearance, and in sucrose in the juice. These morphological characters of parents, seedlings and crosses are illustrated in a series of figures in Plates IX to XI. And this fact also renders it at least probable that many of the first named seedlings, those obtained after dusting *Vellai* arrows with pollen of thick canes, are also crosses, and therefore likely to be of value in cultivation.[1]

The usual collection was made of arrows of local canes from neighbouring villages, and over a hundred pans were sown with these. An analysis of the results rather reverses the conclusions which might have been drawn from a study of the 1912-14 seedlings. In the latter case, while masses of seedlings were readily obtained from *Chittan* and *Karun* arrows, those of *Kaludai Boothan* gave poorer results. But in 1913-15 the *Kaludai Boothan* arrows were extremely fertile, yielding at least 100 seedlings per pan, while *Chittan* and *Karun*, with 70 pans, gave only 300 seedlings together. This reversal was not

[1] NOTE.—This is rendered more probable in that later attempts at raising uncrossed *Vellai* seedlings have failed—Apl. 1916.

unexpected for, as has been stated above, these varieties are closely related, and this could have hardly been the case with so marked a difference in fertility. There is no apparent reason for these seasonal divergences, and the only explanation available is that the arrows might have been of different age or influenced by the state of weather when pollination took place.

Of the arrows received from Bangalore, those of *Ashy Mauritius* and *Striped Mauritius* produced fair results and *White Mauritius* good ones. It is reported that a large number of seedlings have been obtained at Bangalore from the latter cane, yielding a very high percentage of sucrose in the juice, and it is all the more to be regretted that this variety is said to have died out there during the season. A number of arrows of *Java* and *B 208* were received from Bangalore and these proved very fertile, *B 208* giving well over 100 seedlings and *Java* the surprising number of 700, per pan. But the lack of vitality proved to be so great that only 200 seedlings could be planted from *B 208* and 400 from *Java*.

To the same category of canes with fertile arrows but with seedlings unable to withstand the earlier stages, *Red Mauritius* appears to belong. From this variety 1,000 seedlings were raised in one pan, of which only 7 could be planted out. The other canes flowering in the Central Farm were *Striped Mauritius*, *Red Sport of Striped Mauritius*, *Fiji C* and *Fiji B*; these were not very fertile, but most of the seedlings raised were subsequently planted out in the field.

Besides *Java* and *Red Mauritius*, two other varieties have been found of which it is difficult to obtain seedlings, namely *Poovan* and *Fiji C*. But the course of events appears to be different from *Java* in these canes, for the seedlings grew fairly well until planted out in the field, then became light coloured and weak, and few have succeeded well enough in the plots to be worth analysing (*cf.* Pl. XIII). The *Red Mauritius* and *Fiji C* seedlings were from selfed arrows, while *Poovan*, although growing mixed with the other local canes, flowers at a slightly different time and its seedlings are also probably usually selfed.

Besides the seedlings mentioned in the table, a large number were obtained by selfing and crossing such of the Madras seedlings of 1912-14 as flowered, but these were chiefly such as had *Saccharum spontaneum* blood in them and their agricultural value was so poor that they have not been included in the list. The crosses between the North Indian canes *Shakarchynia* and *Chin*, and *Saccharum spontaneum*, in the 1912-14 period, flowered early and abundantly, as seems to be the case with all seedlings with the blood of wild Saccharums

in them, but few had any open anthers, and some of these seedlings were accordingly crossed with one parent, *Saccharum spontaneum*, the only plant with open anthers at the time. No time has unfortunately been available for the study of this interesting series. The spontaneum-like class of seedlings from *Naanal* were, however, provided with abundant open anthers and several of these were selfed as well as crossed by *Saccharum spontaneum*. It is unfortunate that these interesting seedlings flower at a time when no thick canes have yet arrived at this stage for, by selecting the best of them, the way might be opened for obtaining a new set of canes presumably of a very hardy nature. A further small set of seedlings was also obtained in 1913-15 by crossing *Saretha*, another North Indian cane, with *Saccharum spontaneum*.

4. Period 1911-16.

During the first two years, considerable changes were made in the treatment of seedlings after removal from their pots. When the seedlings have been growing for about six months they are transferred from them and planted out in the field. In the first period, 1911-13, as has been stated, the few seedlings obtained were treated very generously, three-foot pits being dug and filled with prepared earth and manure. The conditions in which they were planted made it advisable to treat them as "pot plants," and enough material was provided in the pits for their growth to maturity. Even in these pits the plants were attacked by white ants and certain seedlings were killed, but on the whole their growth was remarkably rapid and healthy, especially in those derived from local parentage. The 1912-14 seedlings, planted on better land and irrigated with less saline water, were put into two-foot pits, in order, if possible, to reduce the great vigour of the seedlings and bring them more into line with ordinary cane plants. The growth was still luxuriant and, in succeeding years, the exceptional treatment of the seedlings was gradually reduced until, in 1914-16, half of them were planted in one-foot holes and the rest in trenches. Concurrently with this, the treatment of the seedlings grown a second year from cuttings was gradually improved, for it was found that the growth of the seedlings when first propagated vegetatively was distinctly precarious, and a certain number of them died out. This attempt at equalizing had also another reason. The analysis of the *Cheni* seedlings in their second year showed a very marked increase in sucrose in the juice, and it was thought that this might be due to the excessive vigour of the seedlings in the large pits. Sufficient evidence has not yet been accumulated on this subject but, on studying any batch of seedlings and their analyses, the general impression makes itself felt that there is an inverse

relation between vigour and richness in the juice, a similar tendency having been noted in indigo and cinchona and doubtless other plants.[1] The whole question is, however, complicated by the fact that the land at Chettipalayam is still largely influenced by having been irrigated by brackish water wells for thirty years and more, and is not of equal suitability for sugarcane growth in different parts.

It has been noted in the description of the seedlings of previous years that those of some parents lacked vitality. *Java* and *Red Mauritius* (and perhaps *B 208*) were characterized by great fertility of arrows, and produced enormous numbers of seedlings in the pans, which, however, soon died in spite of every care. In *Poovan* and *Fiji C*, on the other hand, the seedlings lived until planting out time and then gradually failed, so that the plot in which they were planted became more and more empty towards harvest. It was argued that such varieties would form suitable parents if crossed with hardier kinds, and that, if the seedlings obtained grew with vigour, there would be *primâ facie* evidence that true crosses had been obtained. This line was accordingly taken during the 1914-16 season and a large number of crosses were attempted, chiefly with North Indian canes. Unfortunately, the latter had few open anthers and had to be used as mothers and this particular experiment had to be postponed.

Owing to the great quantity of *Java* arrows obtainable at Bangalore, it was decided to obtain pollen from the canes growing there, for dusting the local arrows at Coimbatore. This led us to a study of the pollen and its vitality. Unexpected difficulties were, however, encountered, in that sugarcane pollen proved very hard to germinate in any of the media usually employed for this purpose, and it was of course necessary to germinate it in order to test its keeping qualities. Some success was ultimately obtained by crushing the stigmas of wild plants flowering at the time, and germinations seem to succeed especially with solutions prepared from the flowers of the prickly pear and *Portia* tree (*Thespesia populnea*). Pollen of *Saccharum spontaneum* appeared to retain its vitality much longer than expected, and after 14 days some of the grains still germinated in these solutions. The sending of the pollen by post would appear to be feasible in small gelatine capsules which are easily procurable and can be readily transmitted without any chance of the pollen drying up.

As a large number of arrows were obtained from Bangalore, it was considered advisable also to test the vitality of cane seed, usually regarded as

[1] Barber, C. A., Some Difficulties in the Improvement of Indian Sugarcanes. *Annals of Applied Biology*, vol. 1, nos. 3 & 4, Jan. 1915, p. 214.

extremely short-lived. A collection was made of seeds of Madras seedlings 2 and 6, *B 208*, *Java*, *Striped Mauritius* and *Saretha*, from the 14th December 1914 to the 5th January 1915, and equal quantities of powdered arrows were sown on the first of each succeeding month. The results shown in the table are interesting, as it is evident that, with proper care, cane seed retains its vitality for a considerable time.

Vitality of Sugarcane Seed.

Variety	Date of Collection	Germination	Feb. 1	Mar. 1	Apl. 1	June 1	July 1	Aug 1	Remarks
Madras No. 2	9th Dec. 1914.	500	500	300	200	100	20	0	Equal quantities of pounded arrow were sown in the first five. Some seed remained capable of germination for seven months. The seed of Saretha survived the longest and that of B 208 had least vitality.
,, ,, 6	15th Dec. 1914.	500	500	300	200	100	20	0	
Saretha ...	14th Dec. 1914.	500	500	500	300	200	40	0	
Java	4th Jan 1915.	500	500	300	100	50	0	0	
B 208	5th Jan. 1915	500	500	300	Less than 100	12	5	0	
Striped Mauritius.	Do. ...	200	200	100	50	12	0	0	A less quantity of arrow sown.

A study of the table containing details of the seedlings raised during the 1914 arrowing season shows a very considerable change in the selection of parents. In the first place, it was assumed from previous experience that the quality of the parents' juice is largely transmitted to the offspring, and an effort was made to obtain as many seedlings as possible of the best canes growing in the various farms. Over 9,000 seedlings were obtained from *B 208*, *Java*, *Striped Mauritius*, *Ashy Mauritius* and *Fiji C* and, of these, more than 1,600 have been selected for planting out. The local kinds, *Karun*, *Chittan* and *Kaludai Boothan* were comparatively neglected, and no collections were made from villages around, as these canes were flowering in the arrowing plots on the station. The results from these arrows were, however, very poor as regards germination and only 50 seedlings were planted out. On the other hand, advantage was taken of the flowering of North Indian canes, and a very large number of seedlings were obtained of *Saretha*. Over 1,100 seedlings derived from North Indian canes were planted out, chiefly of *Saretha*, *Chin* and *Pansahi*. One hundred seedlings were also planted out of Madras Selfed Seedling No. 2 (*Kaludai Boothan* parent), for the special study of the depressed habit which characterizes this seedling, as well as most of those obtained from indigenous canes in India.

Enumeration of 1914-16 *Seedlings.*

1.—ONE PARENT KNOWN OR SELFED.

Variety	Locality	Anthesis, % open	Pans sown	Germination	Planted out	Serial Numbers	Remarks as to Parentage
Striped Mauritius	Mysore ...	10—64%	30	2013	540	5201—5500 5601—5800 6181—6200 6581—6600	B. 208, Java and Striped Mauritius were flowering together and these seedlings are either selfed or possible crosses.
Java ...	Do	92%	19	4000	380	6201—6580	
B. 208 ...	Do	87—98%	32	2770	500	6701—7200	
Ashy Mauritius	Do	48%	14	210	150	7201—7350	Mostly selfed but possibly crossed with Striped Mauritius.
Fiji C. ...	Central Farm ...	?	4	75	50	4851—4900	The arrows were rather isolated. A selfed arrow had 96% anthers open, but when sown gave no seedlings. The seeds were covered by fungus hyphæ.
Vellai ...	Cane-breeding Station.	41—68%	5	4	4	6646—6649	Selfed.
Kaludai Boothan	Do	83%	6	25	23	6678—6700	Kaludai Boothan, Chittan, and Karun flowered together. The seedlings are either selfed or possible crosses.
Chittan ...	Do	69%	6	40	25	6601—6625	
Saretha ...	Central Farm & Cane-breeding Station.	62—81%	15	5400	700	5900—6100 7501—8000	200 were selfed and the rest had no other canes flowering near. Some Chin arrows were open but distant. Probably selfed seedlings.
Chin ...	Do	16—84%	12	330	200	5001—5200	100 were selfed. The rest were probably selfed (*cf.* Saretha).
Cheni ...	Central Farm ...	88%	2	86	60	4901—4960	Selfed.
Pansahi ...	Do	5—18%	6	116	100	4601—4700	6 selfed seedlings and the rest uncaged. M. 2 and M.6 were flowering freely near by and Chynia further off—therefore selfed or possible crosses with these.
Pansahi ? ...	Do	6—11%	7	16	11	5561—5565 5571—5576	6 selfed seedlings and 5 uncaged. The ? is due to a mistake in labelling and it is not likely that these seedlings will be kept.
Chynia ...	Do	23% ?	4	404	40	4961—5000	M. 2 and M. 6 flowering freely near by and Pansahi further off (*cf.* Pansahi)
M. 2 (Kaludai Boothan Parent).	Do	92%	3	200	100	7401—7500	Selfed.

Varieties crossed*	Locality	Anthesis, % open	Pans sown	Germination	Planted out	Serial Numbers	Remarks as to Parentage
B. 208 ...	Mysore ...	95%	3	20	19	5501—5519	Selfed or crossed, but little indication of the latter in the seedlings.
Saretha ...	Cane-breeding Station.	50% ?					
B. 208 × ...	Mysore ...	?	4	70	50	7351—7400	Owing to a mistake in labelling it is doubtful what this is.
Striped Mauritius ?							
Vellai ...	Cane-breeding Station.	30—69%	2	30	27	6651—6677	As in B. 208 × Saretha.
Kaludai Boothan		80%					
Vellai × ...	Do	14—80%	2	15	14	6631—6644	Do.
Chittan ...		68%					
Vellai × ...	Cane-breeding Station.	36—65%	2	1	1	5549	Do.
	Central Farm ...	97%					
M. 6 ...	Mysore ...	92%	4	900	70	6101—6170	Do.
Java × ...	Central Farm ...	76% ?					
Chin ...	Cane-breeding Station.	45%	2	55	50	5801—5850	Do.
Saretha	Mysore ...	87%					
B. 208 ...	Cane-breeding Station.	81%	1	150	50	5851—5900	Do.
Saretha × ...	Mysore ...	92%					
Java ...	Central Farm ...	47%	1	12	10	6171—6180	Do.
Chin ...	Mysore ...	92%					
Java ...	Central Farm ...	71%	2	40	10	5531—5540	Do.
Chin × ...	Mysore ...	87%					
B. 208 ...	Central Farm ...	72%	2	15	10	5521—5530	Do.
Cheni × ...	Mysore	92%					
Java ...	Central Farm	3—8%	3	180	150	4701—4850	Possibly crossed in that Pansahi selfed only produced 6 seedlings, but little trace in the seedlings of Fiji C influence.
Pansahi ×		91—98%					
Fiji C. ...							
Pansahi ×	Central Farm ...	5%	4	3	2	5599—5600	As in B. 208 × Saretha.
B. 208	Mysore ...	87%					
Pansahi ×	Central Farm ...	5—26%	6	8	5	5591—5595	Do.
Java ...	Mysore ...	92%					
Pansahi ? ×	Central Farm ...	5%	2	15	12	5541—5546	Do.
Kaludai Boothan	Cane-breeding Station.	82%				5551—5556	
Pansahi ? ×	Central Farm	4%	2	3	2	5589—5590	Do.
Ashy Mauritius		67%					
Pansahi ? ×	Do	5%	2	6	5	5581—5585	Do.
Fiji C. ...		90%					
Chynia × ...	Do	13%	2	2	2	5559—5560	Do.
Fiji C. ...		73%					
Chynia × ...	Central Farm ...	34%	1	3	2	5569—5570	Do.
Java ...	Mysore ...	92%					
Chynia × ...	Central Farm ...	16%	1	2	2	5579—5580	Do.
B. 208 ...	Mysore ...	87%					
Chynia × ...	Central Farm ...	7%	2	5	5	6626—6630	Do.
Chittan ...	Cane-breeding Station.	69%					

* In all clases the second named parent is the male.

A very large number of crosses were attempted between indigenous canes and thick exotic ones but, on the whole, with very poor results. Pollen was freely sent to Bangalore, where an officer was deputed for three months, to get if possible crosses by *Saretha* and *Chin* on to *Java* and *B 208*, while *Vellai* was crossed, as in the previous year, on the station at Coimbatore. Owing to the poor development of the stamens in most indigenous canes, pollen was brought from the good varieties at Bangalore and dusted on *Saretha*, *Chin*, *Pansahi*, *Cheni* and *Chynia*. But, taking the seedlings obtained after these operations as a whole, there was very little evidence, at planting out, of the influence of the male parent. This strengthens the impression noted below that, if fertile pollen is present in any inflorescence, it is largely prepotent over any foreign pollen introduced and that, in any general collection of arrows in the field, most of the seedlings are selfed, in spite of other varieties flowering at the same time in the vicinity.

Chin'plot (1914-16). Occasional seedlings are met with, which stand out from the rest in some particular. In the figure, one seedling is much larger and more erect, has broader leaves and is flowering earlier than the rest.

VARIATION IN MORPHOLOGICAL CHARACTERS.

The first few seedlings, obtained before starting the Cane-breeding Station, were reared in the Botanic Garden. Their reputed parentage was four local Coimbatore canes and *Cheni* from Mysore. It was noted that the seedlings in each batch differed a good deal among themselves, while those of *Cheni* stood apart as a class separate from the rest. During the next two flowering seasons much time was spent in touring throughout the cane-growing tracts of India and, although occasional notes were made as to differences in the young seedlings, there was no opportunity for going thoroughly into the matter. During the 1914 flowering season, the whole of the 1914-16 seedlings, 3,400 in number, were submitted to a more or less detailed examination before planting out, and have been classified and put into the ground according to the differences noted. The present section, in which some of these variations are discussed, is largely based on the observations made during this examination.

Most of the seedlings fall under the term "General Collection," by which is indicated that no special means were taken to prevent the arrows from being pollinated by neighbouring ones which happened to be protruding at the same time. Some hundreds were "selfed," that is to say, protected from foreign pollen by fine muslin placed over them before emergence. In studying these two classes of seedlings, it has been noted, however, that there seems to be practically no difference between them, and the opinion has been gradually formed that, in the field, where open anthers are present, the great bulk of the general collection are in reality selfed seedlings. It is only in cases where the mother arrows have practically no open anthers that the seedlings have shown, by their intermediate characters, that crosses have been obtained. The descriptions enumerated below have been drawn indiscriminately from batches of selfed seedlings and those obtained from the general collections of arrows.

Vigour and Size.

It is obvious, at a glance, that the seedlings of any one batch differ greatly in size and vigour (Plates I & XII). This is not likely to be altogether due to their environment, as care is taken to treat all in exactly the same manner,

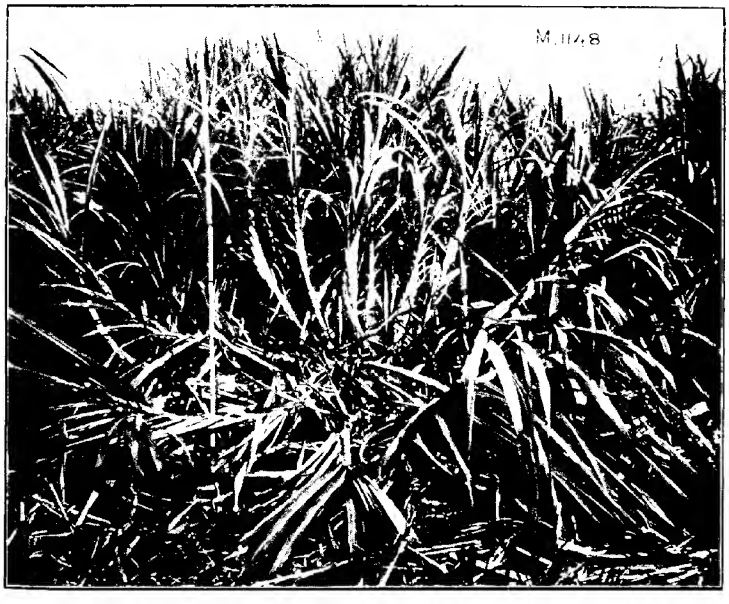
in the soil mixture used, the size of the pots and their watering and exposure to the sun and their ultimate treatment when planted out. It is not easy to determine whether the poor growth of seedlings is transmitted, for the further growth of poor, stunted seedlings, although perhaps of scientific interest, would hardly be defensible, considering the main object of the Cane-breeding Station, and such plants as are obviously inferior in these respects have been uniformly rejected when planting out. The only information as to the future growth of the seedlings which show signs of weakness during their first year's growth is to be obtained from a study of the first (1911-13) seedlings, all of which have been grown on for several years. In these the fate of the weak seedlings is clearly traceable, in that most of them have gradually become weaker and died out one by one, although some of them have shown that they possess very fair juice: and this appears to justify the method of rigorous selection, practised in the young seedlings of any year and also when they are chosen for vegetative reproduction in the second year.

Attention has already been drawn to the fact that the seedlings of some varieties, while coming up in large numbers, quickly die out, thus indicating feebleness in their early stages. Such are *Java*, *Red Mauritius* and possibly *B 208*. In other canes, notably *Pooran* and *Fiji C*, the lack of vigour appears later and, after planting out, the plots of these varieties soon present a sorry appearance, many of the seedlings becoming weak and sickly, and comparatively few surviving so as to be capable of analysis at crop time (Plate XIII). From present appearances, the *Red Mauritius* seedlings suffer all along, but we have had too few seedlings of that variety to be able to state the case definitely.[1] In contrast with these feeble seedling varieties, *Saretha* and *Pansahi* seem to have good germination and healthy seedlings, few of which succumb. Of the 5,000 *Saretha* seedlings obtained in the 1914-16 period, some 1,200 are being grown on, 700 in the plots and the rest in a piece of waste land where they seem to be perfectly at home. There have been hardly any deaths, and there is little doubt that practically the whole 5,000 could have been raised if it had been desirable to do so.

Karun, *Chittan* and *Kaludai Boothan* seedlings are also easy to raise. But this is especially so with genuine crosses, which have thus far in all known cases been exceptionally vigorous. It must be mentioned, however, that most of our crosses, thus far obtained with certainty, have been between North Indian canes and wild parents, but the thick *Vellai* × *Saccharum Narenga* seedlings are very similar as regards luxuriance.

[1] The seedlings of *Red Mauritius* in 1915-17 appear to the more healthy.

Seedling of Poovan & Fiji C plots at crop time. The better grown plants on either side and in the background belong to neighbouring plots.



Two Karun Seedlings (1912-14) showing marked difference in general habit at maturity.

The vigour of any seedling is judged by early rapid growth, ultimate size and, at maturity, by the number of canes and shoots developed, and the total weight of the above ground parts at crop time. In a considerable number of cases it has been noted that seedlings standing out from the rest because of their great growth, have a comparatively low sucrose percentage in the juice. Excessive vigour in a seedling otherwise than a cross is therefore not altogether a desirable character.

General Habit.

There is often marked variability in the habit of seedlings of common parentage (Plates XII & XIV). We shall note elsewhere (pp. 148–149) that the appearance of a variety in the field, often difficult to describe in technical language, is one of the most trustworthy and permanent characters whereby we can distinguish closely allied cane varieties.[1] Height and width of bushes, thickness of canes, width of leaves and the way in which the leaves curve are individual habit characters of value, but we refer here to the combination of several of these and other factors, which gives the whole a definite appearance in the field. (*Cf.* p. 148.)

When the *Saretha* (selfed) seedlings of 1912-14 were nearly ready for reaping, an attempt was made to classify them, using as a guide their general resemblance to other types of North Indian canes; and, on analysing the juice at crop time, it was found that, while the individuals in these classes gave more or less uniform results, the classes differed widely from one another in general sucrose and glucose averages. They were grouped as follows:—

1. *Mungo-Nargori*-like plants. Short erect bushes with moderately narrow leaves curving broadly at their ends, reminding of *Mungo*, some becoming more or less bunched at the ends of the shoots, the short thin stems being clothed with dead leaves, reminding of *Nargori*.

2. Small plants with the bushy habit of *Mungo* but with narrower leaves and some of the outer branches spreading or prostrate.

3. *Saranti*-like plants. Dense, thick, short bushes with the ends of the leaves strict or curved.

4. *Saretha*-like plants. Tall, erect, with stems rather widely separated, the outer canes spreading or obliquely ascending, leaves moderately broad and more or less curved.

[1] This method of classification has been successfully used by Woodhouse and Basu in their description of the Sabour sugarcanes.—*Ibid.*

5. *Shakarchynia*-like plants. Usually tall, erect, strict, with the outer shoots only slightly ascending, stems closely packed, leaf tips not curving, strict.

6. Plants with oblique branches, reminding of birds' nests, or prostrate.

It will be seen, from the figures on Plates XV and XVA that most of these differ very widely from the parent *Saretha*, which is an interesting fact, considering that all the seedlings were obtained from one selfed arrow. The following are some of the characters revealed in their final examination at crop time :—

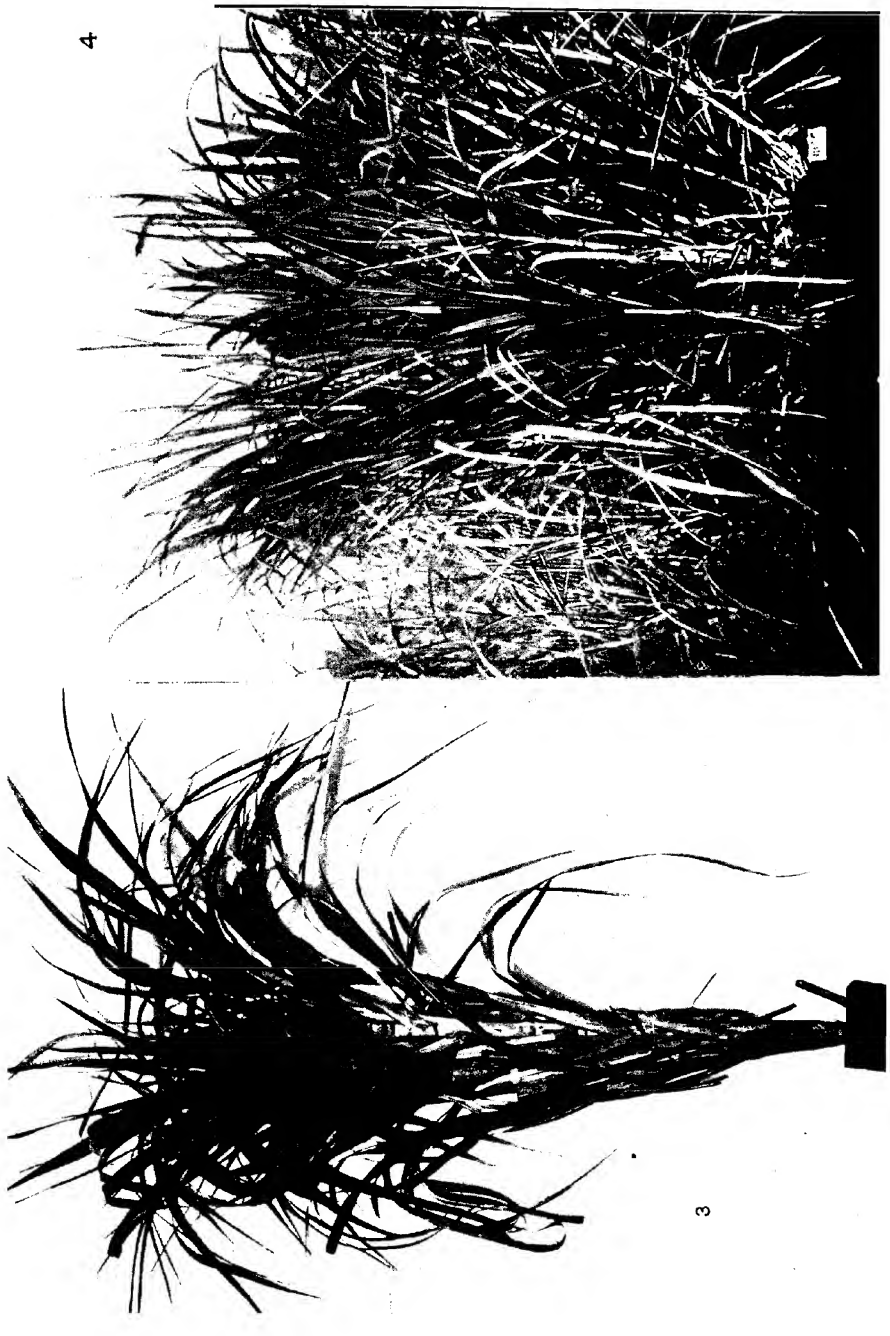
Habit classes	Number of seedlings	Leaf width in inches	Total weight in lb	Sucrose % in juice	Glucose % in juice
1. *Mungo-Nargori*	17	1·06	58	14·64	0·19
2. Small oblique *Mungo* ...	5	0·84	29	15·82	0·14
3. *Sarauti*	2	1·16	69	12·30	0·14
4. *Saretha*	8	1·44	122	14·80	0·12
5. *Shakarchynia*	2	1·27	83	12·34	0·10
6. Oblique or prostrate ...	6	0·94	45	13·58	0·29

From the table it would appear that this line, of separating out seedlings according to habit, may be a profitable one, and it is interesting to note that, taking all the characters together, the class most resembling the parent is the best. It has, however, been found very difficult to distinguish classes of seedlings before they are near maturity.

In the *Naanal* seedlings of the season 1912-14, seven were easily picked out quite early, differing widely from the rest, in that they had extremely narrow leaves, grew very vigorously and took on a strong resemblance to the wild *Saccharum spontaneum*, although obviously not belonging to that species. The rest of the seedlings, with broader leaves, were subdivided according to their erectness and bushiness, characters which change a good deal during the early stages of a seedling (Plates XVI and XXIV). The following were the results of the final examination at crop time :—

Habit classes	Number of seedlings	Leaf width in inches	Total weight in lb.	Sucrose % in juice	Glucose % in juice
1. *Saccharum spontaneum* class	7	0·8	146	6·92	0·29
2. Erect plants with single or bunched shoots.	17	1·3	86	9·08	0·68
3. Bushy plants, broader than tall.	79	1·5	85	8·78	0·65
4. More or less depressed .	57	1·5	91	8·45	0·68

Habit types of Saretha selfed seedlings (1912-14). Fig. 1. Prostrate, with long branches spreading on the ground. Fig. 2. Shakarchynia-like. Fig 5 Oblique, "bird's nest."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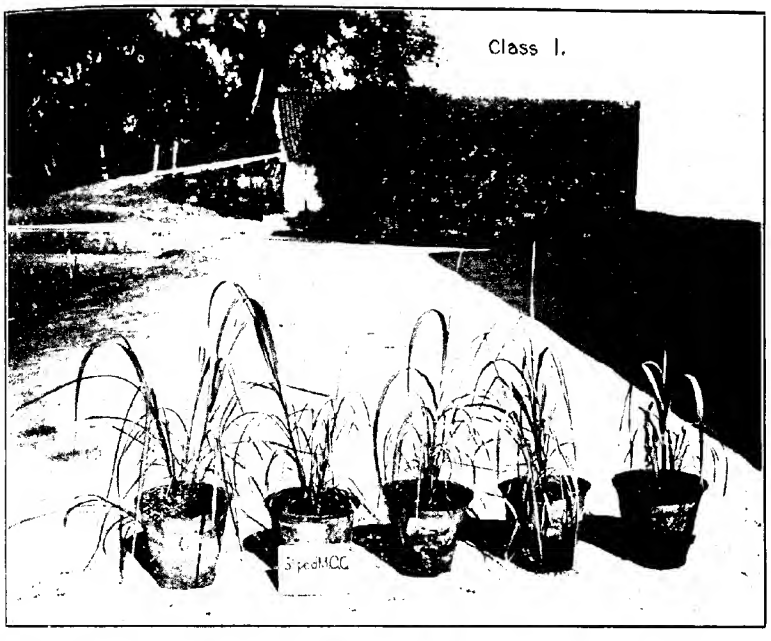
DESCRIPTION OF PLATE XVI.

Naanal seedlings (1912-14). Upper figure, Madras Seedling 1354, narrow leafed and resembling *Saccharum spontaneum* in habit. Note the ground-shoot in the right fore-ground. Lower figure, M.1467, with ordinary cane leaves, but depressed habit (see also Plate XXIV).

PLATE XVI.



An example of habit classes in young seedlings of Striped Mauritius (1914-15).
For description see the text, page 135.

It is seen that the early separation was quite successful as far as the *Saccharum spontaneum* class was concerned, but failed in the other classes, which give more or less uniform results at maturity.

In the examination of the seedlings during the (1914-16) season, considerable difficulty was met with in the attempt to combine several characters and obtain general habit classes while the seedlings were young. It is moreover to be noted that variations in habit are far less marked in the seedlings of thick canes than in North Indian canes. The following may be given as examples of such success as has been obtained. In the *Striped Mauritius* seedlings, 500 in number, some 30 (class 1) were picked out as smallish plants, dark green with some purple in the leaves, with a number of small purple shoots round a central one or two, the latter very erect, with a single, long, vertical, sharp-pointed youngest leaf, the next and succeeding leaves doubling back and heavily drooping, the leaves sometimes revolute or crumpled as if with excessive nutrition. Contrast with these class 12, with tall, wide leaves of a light green colour, the leaf ends strict and unbending until a much later period (Plate XVII). Whether such classes are influenced by unequal nutrition cannot be decided. It is obvious that with equal but limited root space and food material, a smaller plant would be in better circumstances than a bigger one; and this may possibly account for the difference in leaf colouring, but it cannot account for difference in the size of the plants nor in their leaf endings.

One seedling among the 500 *Striped Mauritius* and one among the 350 seedlings of *B. 208* were depressed, narrow-leafed and more or less grass-like, being totally different from the rest in these and other respects. These, among other cases noted during the examination of the 1914-16 seedlings, remind one of the 7 curious plants in the (200) *Naanal* seedlings of 1912-14, which have been referred to already as resembling *Saccharum spontaneum*, the wild *kans* grass. The idea was formed from various facts that these *Naanal* seedlings are not in reality selfed but may be the result of a cross with that species (*cf.* section on Correlations, p. 172), but another explanation is here put forward, at any rate for the seven aberrant forms. It seems possible that we have here cases of "rogues" similar to those described by Bateson and Pellew in culinary peas (*Journal of Heredity*, V. 1). Five of these *Naanal* seedlings were selfed and crossed with *Saccharum spontaneum* in the 1913-15 season. The selfing was expected to result in a splitting by which their original parentage would be indicated. But all the seedlings were of the same type, narrow leafed, reminding of *Saccharum spontaneum*, but obviously not that grass. One of the 500 *Karun* seedlings of 1912-14 (Madras Seedling 1017) at once drew

attention, when planted out in the field, by its great vigour. It had narrow leaves and was very tall and it had a very large number of canes, in fact, it stood out like a tree in its plot, being entirely different to the rest of the seedlings (Plate XVIII). It had little resemblance to *Saccharum spontaneum* and there is no reason for supposing that it is a cross. In fact, it shares with the aberrant *Naanal* seedlings a great flowering capacity, and has with them abundant open anthers and good pollen. This is a character not usually exhibited by crosses between sugarcanes and wild forms of Saccharum. The seedlings of *Shakarchynia* × *Saccharum spontaneum* (1912-14), *Chin* × *Saccharum spontaneum* (1912-14); and *Vellai* × *Saccharum Narenga* (1913-15), while extraordinarily vigorous and flowering profusely, were almost entirely infertile, as regards their male organs, the anthers being persistently closed and with unformed pollen.

Erectness of Young Shoots.

This is judged by measuring the angle made by the young shoots with the vertical line. As will be seen later, this angle varies with the age of the plant. All stages are met with in the seedlings between strictly vertical shoots and those depressed so as to be parallel with the ground, and there seems to be a connection between this obliquity in the seedlings and in their parents when planted from sets in the ground (Plate XIX). There is, furthermore, a great general difference between the thick canes and their offspring and the indigenous Indian canes and their seedlings in this respect, comparatively slight obliqueness being met with in the former. Such depressed habit in early growth is not unknown elsewhere. Besides many grasses, it is common in "wild paddies" and in certain wheats. It is also to be found in other classes of plants. For instance, the young plants of *Acacia leucophloea*, a perfectly erect tree, are often found lying prone on the ground.

In *Striped Mauritius*, *Ashy Mauritius*, *B. 208* and *Java*, the parent shoots appear rarely to deviate from the vertical more than 20 degrees, and, in their seedlings, of which some 1,500 have been raised during the present season, the only two marked cases of depressed habit have been mentioned above, as solitary plants among the *Striped Mauritius* and *B 208* seedlings. *Karun*, *Chittan* and *Kaludai Boothan* seem to be similar in this character, but there were comparatively few seedlings raised in these varieties during the year. There would seem to be more obliqueness in the young shoots of *Vellai* than is usual in thick canes, but comparatively few seedlings were obtained from this cane during the year. A seedling raised in 1911-13, Madras No. 2 (*Kaludai*

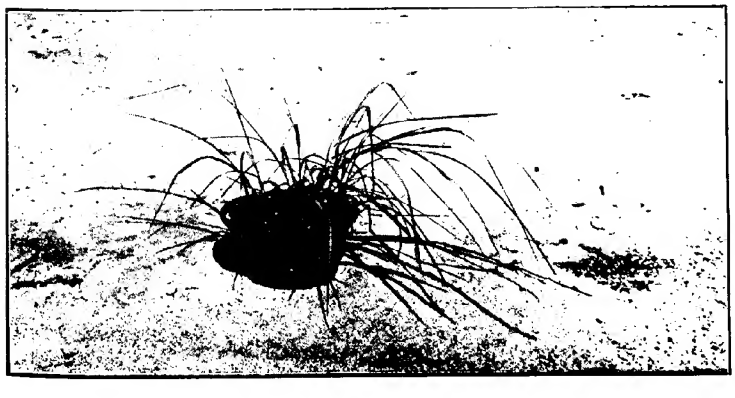
Madras Seedling No. 1017, a Karun (1912-14) seedling differing markedly from its neighbours. This difference was maintained when replanted from cuttings and the figure shows its growth in 1915-16. It is in "shot blade," as is its neighbour on the left.

DESCRIPTION OF PLATE XIX.

Chin parent and seedlings (1914-16), showing obliqueness. The upper figure shows the most erect seedlings and the middle the most oblique. The lower figure shows a cutting of *Chin* of about the same stage of growth as the seedlings. The obliqueness of its shoots is marked.


331
331
Chin C.C.
Erect.
330


330
330
330
Chin C.C.
Oblique.



Saretha seedlings (1914-16), 5½ months old and about to be planted out. A few of the rare, erect seedlings are figured, as well as some with the central, oldest shoot curving outwards and downwards, the later shoots being much more erect.

DESCRIPTION OF PLATE XXI.

Saccharum spontaneum seedlings. The upper figure shows growing set plants from erect and prostrate seedlings, separated in 1911-13, and grown on. The lower shows a young plant of the latter. The canes in the background of the upper figure are narrow leafed, North Indian varieties, indicating the extreme narrowness of the leaves of *Saccharum spontaneum*.

Boothan parent) was, however, markedly oblique. There is some doubt as to the parentage of the seedlings collected at Coimbatore during that year, and this seedling differs a good deal from the *Kaludai Boothan* seedlings of 1912-14. It has now been carefully studied for some years and certain facts noted. In the first place, in it and the cases cited below, obliqueness tends to increase when the seedling is propagated by sets in the second year (*cf.* Plate XXIII). Secondly, of 100 selfed seedlings of Madras No. 2, only four show any trace of erectness, the rest being practically prostrate. Thirdly, when these seedlings were examined before planting out, there was little trace of the prostrate habit, owing doubtless to their being planted in pots and placed close together in the irrigating trenches. This is one of the directions in which the new system of saving labour in irrigating potted seedlings has worked badly, namely, in hiding the true character of the seedling (*cf.* p. 149).

Among Indian canes, *Naanal* is generally characterized by erect young shoots. But, among the seedlings raised in 1912-14, a great number showed a more or less depressed habit, possibly another reason for assuming that these seedlings were not pure *Naanal*. In *Pansahi*, although the mature plants are strikingly erect, there is a good deal of obliqueness in the young shoots, and this is reproduced in the seedlings, many of which show oblique or even prostrate shoots (*cf.* Plate I). *Chynia*, another member of the same class of North Indian canes, has young shoots which are practically erect and, although the seedlings are less oblique than in *Pansahi*, there are some which show depression. *Saretha* has very oblique young shoots and the seedlings are rarely erect, most of the 1,200 examined in 1914-16 being more or less oblique and many actually prostrate, and the same applies to *Chin* and its seedlings planted out in the same year (*cf.* Plate XIX). A special form of oblique shoots has been met with in these two varieties which is most striking. The first, oldest shoot, arising with slight obliquity, subsequently curves outwards and downwards and becomes very depressed, while subsequent shoots may be more or less erect. This peculiar habit is shown in *Saretha* seedlings in Plate XX ($5\frac{1}{2}$ months old) and is there contrasted with some of the rare erect seedlings.

It is interesting to note that the growth of *Saccharum spontaneum* resembles that of *Chin* and *Saretha* in many respects, including obliqueness and the characteristic outer, ascending shoots. Some of its seedlings have very oblique young shoots and one of them grown on from cuttings has become practically flat on the ground (Plate XXI). Crosses between *Saccharum spontaneum* and *Chin* and *Shakarchynia* (the latter a strict, erect cane from

Bihar) show this obliqueness very markedly. There is, in fact, general evidence that if there is any obliqueness in the parents, it comes out strongly in the seedlings and more so still when the latter are reproduced from cuttings.

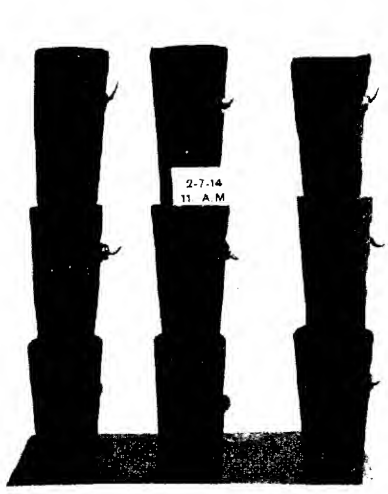
The thirty-eight 1911-13 seedlings have now been grown for several years successively from cuttings, and notes and photographs have been taken at various stages in their growth. *Cheni* is marked by considerable obliqueness in its young shoots, and this has come out in the seedlings, all of which show this character in varying degree. By comparing the photographs taken it has been noted that, while the oblique character is distinctly traceable in all the seedlings at four months from sowing the seed, it increases until the seventh month, and then diminishes until, in the tenth, there is little trace of it left, the shoots gradually becoming erect as cane is formed. On making a similar comparison in the case of young shoots of these seedlings planted from cuttings, the obliqueness seems to be greatest at four months and, by six months, it has more or less disappeared. A series of photographs taken of growing sets of Madras No. 2 shows this change in habit very well, the angle of growth having been traced, in several cases, from germination until flowering. The mature cane is seen to be sinuous in shape, commencing at an oblique angle, this followed by further depression and finally erecting itself as the flowering period is approached. A paper on this subject was read by M. R. Ry. T. S. Venkataraman and myself at the Madras Science Congress in January 1915, and some of the lantern illustrations are here reproduced (Plate XXII).

It is natural to connect this early obliqueness of the shoots with a more or less straggling mature habit of the canes, and there appears to be some reason for doing this, in that *Chin* and *Saretha*, when growing luxuriantly in the field, are liable to fall and have to be propped. But it has been difficult to trace this connection in many cases and, on the cane-breeding station, the heavy winds and unusual rains during the past season have caused almost all the canes to fall and they have had to be raised and tied to bamboos, thus hiding their natural habit. Some canes showing early obliqueness quickly recover erectness, as for instance Madras No. 2 Seedling (Plate XXIII), but others, and especially some *Saretha* seedlings, remain prostrate for a great part of their existence. The time at which oblique shoots raise themselves and become ascending is at present undetermined in a large number of cases of seedlings, although it is fairly early in most cultivated canes. The seedlings of any batch, especially of North Indian canes, vary greatly in early erectness and, in consideration of its important agricultural bearing, marked attention has been paid to this character in classifying the seedlings in 1914-16.

DESCRIPTION OF PLATE XXIII.

DESCRIPTION OF PLATE XXII.

The figures illustrate the growth of cuttings of Madras Seedling No. 2 (*Kaludai Boothan* parent, 1911-13), from germination until the flower stalks are formed. Figs. 1-6 are of germinated sets, placed opposite holes in the sides of vertically placed pots. Of the 9 sets shown in Fig. 1, four were chosen in Fig. 2, to show how the degree of obliqueness increases with size. Three of these are shown at further stages in Figs. 3-5, and one of them is photographed in Fig. 6 just before flowering. Figs. 7-12 show a similar series, with one germinated set planted upright in a pot. The obliqueness is already very marked in Fig. 8, 18 days after planting, and in Fig. 9 it is shown that the downward tendency is hampered by the edge of the pot. The plant was raised and replanted on a heap of earth and stones in a bigger pot, and Fig. 10 shows further depression. In Fig. 11, erection has commenced and, in Fig. 12, the flowering stage is reached. (I am indebted to Mr. T. S. Venkataraman for taking these photographs which were prepared for a paper read by us at the Madras Science Congress of January, 1915)



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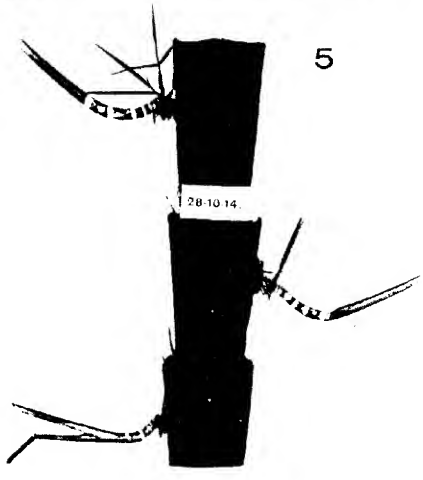

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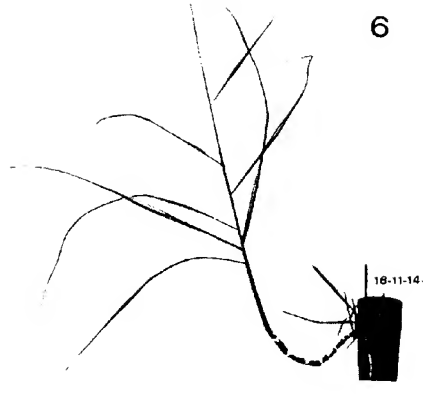

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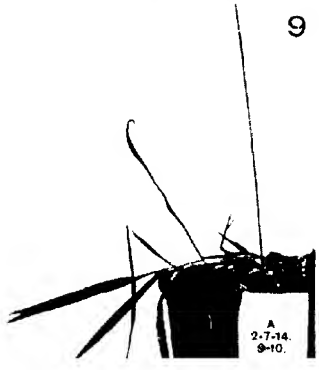

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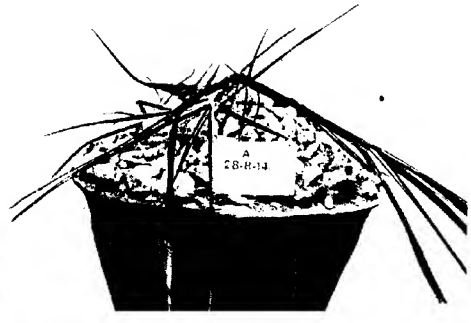

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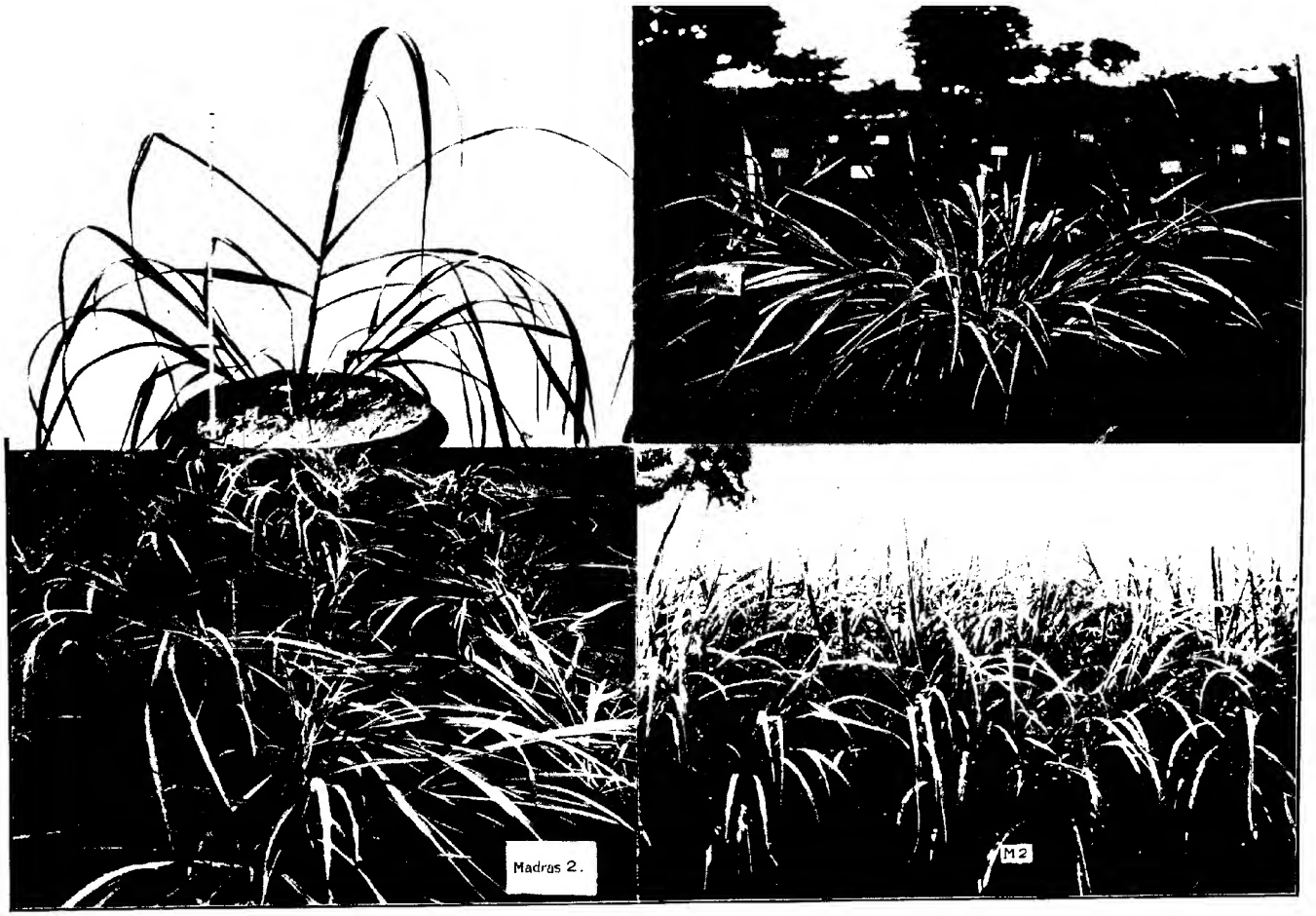
DESCRIPTION OF PLATE XXIII.

The obliqueness of shoots in Madras Seedling No. 2. Fig. 1. Seedling 4½ months old. Fig. 2. The same, 7 months old. Fig. 3. Germinated cuttings (second year), 3 months old. Fig. 4. The same. 6 months old.


Madras 2.
M2

Naanal seedling (1912-14), with poor early tillering, a single strong shoot being formed without small shoots at the side. With this may be compared the Naanal seedlings of the same batch and about the same age in Pl. XVI.

In conclusion, the depressed habit referred to above is not an uncommon occurrence. Many of the Gramineæ show two markedly different growth stages, the first consisting of much branching of low shoots and the second of the erection of flowering spikes. But this habit of growth is not altogether disadvantageous, for it does not diminish the number of ears of grain borne aloft at harvest time. In the sugarcane the inflorescences are also erect, but that is of little importance, and the twisted nature of the stem is a matter of real concern.

Tillering.

Tillering varies a great deal among seedling canes, and the cause of this is not understood. Many of them, especially among the thicker canes, at first develop a single cane-like shoot which becomes quite large before any others are formed. Others again send out a number of smaller equal shoots which continue to grow for some time before one of them becomes a leading shoot and outstrips the rest (Pl. XXIV. See also Pl. XVI). The two extremes are usually only met with in the Indian canes, where we get, on the one hand, a single cane-like shoot and, on the other, a dense mass of small leafy ones with thin leaves, for all the world like a tuft of grass (*cf.* Pl. XIX). The latter form is not generally found in the seedlings of thick canes where, however, it is not infrequent for a seedling to develop a number of tallish, graceful branches so as to resemble a full grown plant of *tenai* (*Setaria italica*). No connection has at present been established between the number of shoots early developed and the mature habit of the seedling but, as a rule, seedlings of Indian canes have, like their parents, far more branches than the thick tropical ones. This is readily seen in the accompanying table.

Tillering in seedlings of various parentage.

	Parentage	Number of seedlings	Average number of canes	Average number of small shoots	Remarks
Thick Canes ..	Chittan ...	489	13	6	
	Karun ...	308	13·5	4·5	
	Kaludai Boothan	57	15	6	
	Poovan ...	13	11	6	
Indian Canes ...	Naanal ..	180	A great number, but not counted.		The number was especially large in "Spontaneum class" (*cf.* Pl. XVI)
	Saretha ...	49	Together 52		
	Cheni ...	18	44	13·5	
Cross with Wild Cane.	Shakarchynia × *Sacch. sponi.*	62	81	Not noted	(*cf.* Pl. VI.)

Leaf Tips.

One of the most striking habit differences in cultivated canes is the form assumed by the ends of their leaves. Some, like *Shakarchynia* (Pl. VI, fig. 3), have stiff, unbending tips; others have a sharp bend or break near the end, as in most, if not all, of the *Chin* alliance (*Chin, Saretha, Katha, Kansar, Lalri*)[1]; others again, although moderately stiff, soon bend slightly as in the *Mungo* group; while the *Pansahi* group, consisting of *Pansahi, Yuba, Maneria, Lata, Dickchan, Sanachi, Kaha*[2] etc., have broad leaves which, from the first, soon bend in wide and graceful curves. There are similar differences in almost every batch of seedlings which has been examined. It is true that in many plants this curving of the leaf ends depends a good deal on the rate of growth and the amount of food and moisture available. Differences can be seen in any field of young *cholam* or *juar* (*Andropogon Sorghum*) (Pl. XXV), and on the banks of the railways among the various specimens of the stronger wild grasses, but, considering the fact that it is attempted to grow all the seedlings under identical conditions and that the varieties of cultivated canes differ so markedly in this respect at maturity, a good deal of attention has justifiably been given to the leaf tips in examining the seedlings. The bending does not seem to have anything to do with the width or the length of the leaf, nor with the general conditions of the plants and, accordingly, one of the first selections has been to pick out all the plants with strict, erect leaves whose tips do not soon bend. It was generally possible, in the 1914-16 seedlings, to obtain about 10% in each batch with erect tips, but *Cheni* and *Java* showed a stronger tendency towards this character. Most of the seedlings had leaves soon broadly curving, while here and there it was possible to pick out such as were distinguished by the leaves being bent back so that the upper part was almost parallel with the lower (*cf.* Pl. XVII).

Width of Leaf.

There is great variation in the width of the leaf in any batch of seedlings of common parentage (Pl. XXVI), while the general average width in different batches often hints at their parentage. In fifty young *Cheni* seedlings (1914-16) this variation was from 0·45″ to 0·90″, the broadest leaf being chosen in each case, and in *Kaludai Boothan* the difference was between 0·6″ and 1·3″. At

[1] Barber, C. A. *Mem. Dept. Agr. Ind. Bot. Series*, Vol. VII, No. 1, Pls. III and IV.
[2] *Ibid*, Pl. XVI.

Young *Cholam* plants (*Andropogon Sorghum*), grown on the Cane-breeding Station. They were all sown at the same time, but those on the left are in a damper place. The difference in leaf tips is marked.

Chittan seedlings (1914-16). Typical broad and narrow leafed classes.

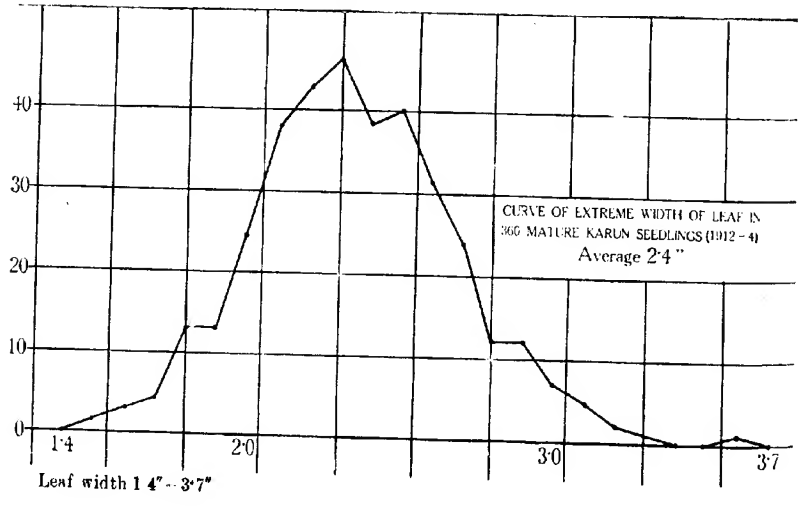
the first glance it is natural to assume that, in this leaf width, carrying with it greater assimilative power, there may be a difference in the ultimate value of the seedling and the quality of its juice. And this suggestion receives support in that the indigenous Indian canes are, as a whole, characterized by extremely narrow leaves as contrasted with canes grown in the tropics. Thus, the width of a leaf in the *Chin* group might be anything from 0·6″—1·3″, in the *Pansahi* group from 1·5″—2·0″ and in exotic canes from 2·0″—4·0″.

Considerable attention has accordingly been paid to leaf width in the seedlings examined. It must be conceded that there is a great deal of variation in the width of the leaves of each individual seedling, dependent on the vigour of growth and the age and position of the leaf on the stem. In order to obtain a common basis, it was decided to measure the widest leaves observable. All the seedlings are thus measured at crop time, ten shoots being taken and the widest in each measured and an average struck. This has given on the whole satisfactory results, and ordinary variation curves have been obtained for each set of seedlings. That for 360 *Karun* seedlings is appended below. But it has been found that this method is unsafe if applied to young and growing plants. In a batch of half grown *Karun* seedlings (1912-14), 236 in number, this method of averaging the widest leaf was adopted, but the classes resulting, when compared with those obtained in the same seedlings at crop time, showed many serious discrepancies, and this has led to a study of the leaf width of sugarcane plants at different periods of growth. In a growing shoot it was observed that, for a considerable period, each new leaf was on the average wider than its predecessor and thus, in seeking the widest leaf, this was usually found near the apex of the shoot. It is obvious therefore that the leaf width of any seedling, judged by this method, will be influenced by its relative vigour of growth as compared with its neighbours. The more rapidly growing seedling will obtain a higher place in leaf width than is justified by its ultimate development. It has not yet been ascertained at what stage the maximum leaf width is reached, but experimental measurements are being made with a set of plants to determine this. It has been assumed that, in fully matured plants with healthy leafy shoots, this error is eliminated, although it is possible that, by this time, a converse diminution of leaf width may have set in.

The accompanying table gives the leaf widths of the 1912-14 seedlings with approximate figures for their parents.

Average extreme leaf width of mature seedlings and parents.

Parents	Seedlings			Parents		Notes
	Number of seedlings	Extreme cases	Av. of all the seedlings	1	2	
Chittan ...	529	1·4–3·6	2·4	2·4	2·5	Each figure was obtained by taking 10 shoots, measuring the widest leaf and taking an average of the ten.
Karun ...	360	1·4–3·7	2·4	2·4	2·3	
Kaludai Boothan	75	1·3–3·3	2·4	2·5	2·8	The average of all the seedlings in Chittan, for instance, is the grand average of the averages above mentioned in all the 529 seedlings.
Poovan ...	13	1·7–3·0	2·2	1·8	2·0	
Cheni ...	19	0·9–2·4	1·6	2·4	2·0	The "Extreme Cases" are the lowest and highest averages obtained in these 529 seedlings.
Naanal ..	73	0·6–2·1	1·4	1·9	1·65	Two sets of observations were made for the parents, but in neither case were these well grown. The figures for the parents are thus only approximations.
Saretha ..	45	0·4–1·9	1·0	1·1	1·3	
Shakarchynia × *Saccharum spontaneum*	64	0·3–1·3	0·8	0·9 0·4	1·25 0·4	Graphs were prepared of all the sets of seedlings, of which one (Karun) is reproduced below. The others were similar



With actively growing seedlings another method has been adopted which it is hoped will lead to more satisfactory agreement with the comparative leaf width at crop time. This consists in viewing well-grown plants of the same age at a short distance, estimating the average leaf width and measuring a leaf which seems to represent this average. The following are variations recently obtained in this manner, *Ashy Mauritius* (150) 0·7″—1·9″, *Striped Mauritius* (500) 0·8″—1·7″, *Chynia* (60) 0·8″—1·75″, *Pansahi* (250) 0·7″- 1·2″, *Chin* (200) 0·25″- 0·90″. This method of judging the average is not very applicable to mature seedlings, because of their height and general inaccessibility.

Colour of the Leaves.

There is considerable difference in the leaf colour of different varieties and species of Saccharum. *Saccharum spontaneum* has bluish green leaves *Saccharum arundinaceum* light grass green and *Saccharum Narenga* has more of a brownish tinge in the green, as grown at Coimbatore. *Katha* has glaucous green leaves and is thus readily distinguished from *Dhaulu of Gurdaspur* in which the bluish colour is less apparent, while members of the *Nargori* group may be frequently distinguished by a peculiar coppery brown tinge. In thick canes there are similar variations in tint which appear to be of taxonomic value. Among the seedlings examined, a glaucous tint is often met with in those of *Chin* parentage, and occurs in most of the seedlings which have *Saccharum spontaneum* blood in them. Some of the seedlings of *Java*, *Striped Mauritius*, *B 208* and *Saretha* have a marked purple tinge in the leaves, and in the two former varieties this colour invades the midrib, which becomes, in the absence of green there, a strong violet. Besides this, there are colorations due to the invasion of specific fungi, which seem to occur in certain seedlings and not in others. Striping of the leaves has not as yet been met with in the seedlings of indigenous canes, but it appears occasionally in seedlings of thicker canes. In *B 208*, *Striped Mauritius*, *Java* and some others, striped leaves occur regularly in about 2% of their seedlings. This is probably connected with incipient striping of the stems, a very rare occurrence in seedling canes (*cf.* under colour of canes, p. 146).

A marked difference can sometimes be noted between seedlings with dark green leaves and those of lighter, yellowish green, but this difference may be either inherent or due to alkalinity or salinity of the soil or irrigation water, and this fact makes it necessary to exercise some care in classifying the seedlings according to this character. There is hardly anything in which cane varieties differ more than in their capacity for resisting excess of salts in the soil and, as there is a good deal of salinity in the Cane-breeding Station, this

has been carefully studied (*cf.* Pl. VII and the text). The first indication of the effect of salinity is seen in the yellowing of the leaves. An interesting fact was noted in a batch of *Saretha* seedlings transplanted direct from the pans into the ground, when three months old. A preliminary separation was made, at six months, between dark green seedlings and such as had light green or yellowish green leaves, but the final examination was delayed for a week, after which some of the dark green seedlings were noted to have become yellow. There was heavy rain during the week. The cause of this was at once understood, and may be explained by the curious effect produced by heavy rain shortly before the Agricultural Conference met at Coimbatore in 1913. The field of cane varieties was healthy and dark green, when a couple of inches of rain fell, and the whole field turned yellowish. After some study, the following explanation was offered and this has been substantiated by further observations. The slightly saline land, during irrigation in the trenches had accumulated a layer of brown, powdery earth just above the point to which the water reached, each ridge showing this layer distinctly at the point where, presumably, evaporation was strongest (Pl. XXVII). On analysis, this powdery earth showed the presence of as much as 11% of salts, chiefly sodium chloride, and the heavy downpour appears to have washed the salt down to the roots of the canes with resulting yellowing. Any attempt at classification according to the light and dark green colour of the leaves of seedlings must be approached with caution.

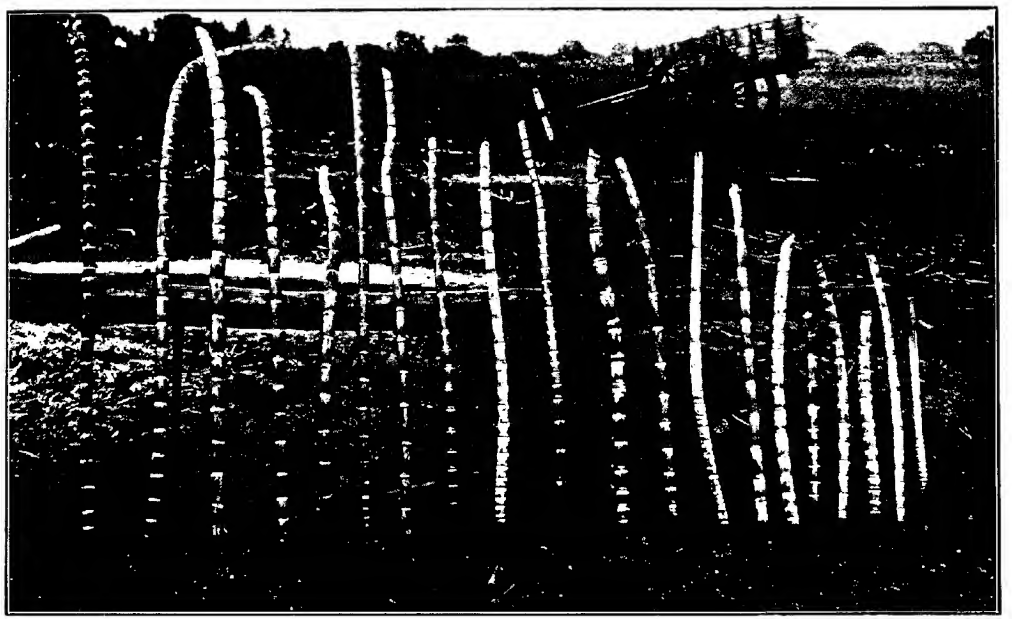
Coloration of the leaf sheath, other than that due to disease, is a well marked distinguishing character in young seedlings, although it becomes difficult later on. The sheaths may be pure green, although this is comparatively rare. They are usually tinged with light purple, pink or a vinous colour. Sometimes they are strongly violet or bluish purple or even a clear pink, and a number of classes have been instituted according to variations in the colour of the leaf sheaths, which is rarely constant in any batch of seedlings. The colour of the very small shoots, although depending primarily on the colour of the leaf sheaths, appears to be of a somewhat different character. They are either green, purplish green, dark purple or sometimes almost black.

The colour of the transverse marks (the small triangular patches of colour on each side at the base of the lamina where it joins the sheath) is easily seen in young seedlings, and affords a useful separation character. The colour varies from very dark chocolate to purple, reddish and brown to wax coloured, yellow, green and greyish white, the latter probably owing to bloom.

PLATE XXVII.

DESCRIPTION OF PLATE XXVII.

Formation of a layer of brown, powdery, saline earth in irrigated trenches in the Cane-breeding Station. This was on untreated land where the canes were first planted in 1913. For details of this powdery earth, which is formed at the point of greatest evaporation, consult the text. The poor growth of the thick canes is seen at the side. The central portion was unplanted.



Average canes taken from 20 Karun seedlings (1912-14), harvested on one day (May 6). These were in no way selected, but merely such as were analysed in rotation on the same day. The canes show marked differences in length and thickness, size and shape of joints and, obviously, in colour, although the latter is only indirectly indicated by differences in shading.

Colour of the Canes.

In no respect do the seedlings of any one batch differ more widely among themselves than in the colour of the canes (*cf.* Pl. XXVIII). It is moreover extremely difficult to classify these colours, because of the number of different shades in any one cane, and it is probable that each observer would adopt a different system of grouping. It is, naturally, not possible to determine the colour of a cane in very young seedlings and the following facts have been elicited from a study of the seedlings of 1912-14 at crop time, the colour of all having been recorded when they were prepared for final chemical analysis. The classes adopted were as follows:—

(1) Green, including various shades of green, yellow, grey to almost white through heavy bloom, there being no tinge of brown, pink, red-brown or purple present.

(2) Brownish and vinous tinged greens.

(3) Purple, claret and red, the latter being rather indefinite, but neither claret nor purple.

(4) Striped.

Subjoined is a table giving the colours of the parents and the proportional colours of their offspring.

Colour of canes in seedlings and parents.

Parents	Colour of parent	Number of Seedlings	Green	Brownish	Vinous	Brown or Red	Purple	Claret	Striped	Remarks
			%	%	%	%	%	%	%	
Chittan ...	Striped, claret and green or yellow.	468	56	14	8	3	14	4	0·04	Striping of parent breaks down.
Karun ...	Claret ...	537	44	9	8	14	5	17	0·1	Comparatively large percentage of clarets.
Kaludai Boothan	Greyish green with vinous tinge.	56	43	10	43	2	...	2	...	Comparatively large percentage of vinous.
Saretha ...	Green when young becoming brown or red when old.	50	46	...	8	46	...	...	...	Comparatively large percentage of browns and reds.
Naanal ...	Green ...	84	46	33	20	...	...	...	...	Greens with brownish and vinous tinge.
Cheni ...	Green ...	25	80	12	8	...	...	...	...	Too few seedlings available.
Poovan ...	Greyish green.	14	29	13	29	7	21	...	...	

There are one or two interesting and unexpected features brought out in this table. In the first place, the colour of the parent has some little influence, although comparatively little, on the colours to be found in the seedlings derived from it. This influence is seen in the comparatively larger proportion of clarets in the *Karun* seedlings, vinous in *Kaludai Boothan* and *Poovan*, browns or reds in *Saretha* and greens in *Cheni*. But it is a rather curious fact that the proportion of the greens is fairly uniform in most of the groups. With the exception of the last two classes in the table, in which few seedlings were available, this proportion is more or less 50% of the total number of seedlings in each case. Of the total 1,031 seedlings in the list, 49% are greens.

The question of *Striping*, again, is always of interest. One would expect that, in the seedlings of *Chittan*, a striped cane, there would be a larger proportion of cases with striping in the stem. But this does not appear to be the case. The striping breaks down completely in the seedlings, and, when it occurs, it is connected with striping of some of the younger leaves. It appears that this coloration arises as a sport in one-colour canes. The following instances of this have been noted in recent years in Madras, and there are doubtless others which have escaped the rather perfunctory attention given to the subject. *Red Mauritius* (a dull or dark claret cane) has been observed to sport in two directions. A variety of common appearance has full and dark red stripes, and another less common one has an element of green alternating with the red. A set of *Maneria* (a greyish green cane) plants received from Sabour has shown several striped sports. *B. 376* shows occasional striped sports, and a striped sport is recorded of *B. 1529*. Most of these have been subsequently lost, from one cause or another, and in a good many cases the striping was not very pronounced. Once, however, a striped cane has arisen, it frequently splits into its two component colours. Thus, in every field of *Striped Mauritius* and *Striped Tanna*, green sports are found, in the latter case the green or yellow easily blushing bright red in the sun, as this colour does in the parent stem. *Striped Singapore* (possibly a local variation of *Chittan*) has been observed also to produce greens. Red sports are less common, but a well authenticated case has been met with in *Striped Mauritius*, the cane thus arising being of considerable agricultural value.[1]

Thickness of Canes.

This was measured at crop time in the 1912-14 seedlings. As seen in the accompanying table, the thicker canes produced the thicker seedlings, and the

[1] Note In recent examinations of indigenous Indian canes, a faint striping of one or two joints has been not infrequently noted, April 1915.

range of variations in any batch of the same parentage is more or less constant, the thinnest cane being, roughly, half the diameter of the thickest. The thickness was determined by spreading out 20 canes, selecting the average and measuring it at the middle. The accompanying photograph (Pl. XXVIII) gives some idea of the variation in seedlings of the same parentage in this and other respects.

Thickness of canes in seedlings and parents.

Parents	Thickness in parents	Number of seedlings	Extremes in thickness of seedlings	Average thickness in seedlings	Notes
	cm.		cm.	cm.	
Chittan	2·7	473	1·5 - 4·4	3·2	The thickness in any seedling was judged by spreading out 20 canes, selecting an average one and measuring it at the middle in a plane at right angles to that passing through the bud.
Karun	2·9	318	2·0 - 4·9	3·3	
Kaludai Boothan	3·2	56	2·4 - 4·1	3·2	
Poovan ...	3·1	11	2·2 - 4·0	3·1	
Naanal ...	2·1	65	1·3 - 2·8	2·1	The thickness of the cane in the parents is an average of previous measurements found in the notes on these varieties grown in various places. Measurement was done by calipers and is in centimetres.
Cheni ...	2·2	18	0·6 - 1·2	2·0	
Saretha	1·5 - 2·0	43	1·1 - 2·3	1·8	
Shakarchynia	1·5 - 2·0	62	0·8 - 1·6	1·1	
× *Sacch. spontan.*	0·5 - 1·0				

The above mentioned are the chief characters in which young seedlings have been found to vary. Other minor differences, such as length of internode (usually greater in Indian canes), flatness of leaves (whether incurved, revolute or crumpled), colourings due to minor leaf fungi or insect or other attacks, and so forth, have been noted, but the results are at present too vague to be used in classification. The whole of the 3,400 seedlings planted out in 1914-16 have been divided up into groups according to these characters, and the following classes in 500 *Striped Mauritius* seedlings (general collection) may serve as a type of the method adopted. The seedlings were examined in two lots, of 300 and 200, which accounts for duplication of classes.

Class 1.—(40 seedlings) Some purple in the leaf.

Class 2.– (50) Plants with bright pink leaf sheaths.

Class 3.—(9) Some striping in the leaves.

Class 4.– (30, practically all that were discoverable) Sheaths green, with hardly a trace of purple or pink.

Class 5.—(40) Leaves revolute or, at any rate, sinuous.

Class 6.—(20) Leaf tips with a sharp backward curve, the youngest leaf usually with a long erect point, otherwise resembling the last class.

Class 7.—(20) *Tenai*-like seedlings (*Setaria italica*).

Class 8.—(20) Broad leafed plants, with strongly growing shoots, the broadest leaves of which varied between 1·6″ to 2·0″ in width.

Class 9.—(20) Narrow leafed plants, with strongly growing shoots, the broadest leaves of which were less than 1·3″ wide.

Class 10. (20) Transverse marks sharply coloured.

Class 11.—(20) Transverse marks not strongly coloured, often pale green or yellowish.

Class 12.- (10) Leaf tips erect (only 12 being met with).

Class 13. (40, all that could be found in 200) Duplicate broad leafed lot, widest leaves varying between 1·3″—1·6″.

Class 14.—(40, although more could have been obtained in 200) Duplicate narrow leafed lot, widest leaves under 1·3″.

Class 15.—(10 plants, all that could be obtained in 200) An addition to class 6, small, slender, dark green seedlings with poor tillering.

Class 16.—(30) More or less bushy plants, with or without a main strong shoot.

Class 17.—(30) Not bushy, with strong main shoot and few others.

The remaining 32 unclassified, with 8 selfed seedlings added.

A certain amount of correlation between some of these characters is noticeable (see also General Habit classes, p. 133 *et seq.*). Thus the "*Tenai*-like" plants, resembling *Setaria italica*, with a number of equal but not very strong shoots, are usually of a light green colour, and their leaves are narrow and bend gracefully at the same angle all round. The typical purple-leafed plant has dark green foliage, the plants are usually small but look very healthy, the young shoots are very dark in colour and the leaves bend back very sharply, often with one very long, acicular point in the middle of the plant. The pink-sheathed plants are often large, with comparatively few shoots and without dark coloured small shoots. The erect-tipped leaves usually belong to plants of a pale green colour, often broad leafed, and so forth. These correlations have not been definitely settled, but they give the impression that further study will show that certain infantile characters of the seedlings will be found to be related and, if this can be proved, a great step in advance will have been made, for all present indications point to the fact that any classification of the cultivated sugarcanes must be based on the accumulation of a number of,

often very minute, morphological characters which, taken together, give the plant an indefinable but real form of habit.

One of the chief difficulties met with, in this habit study, has been (as already stated) that the method of arranging the seedlings in their early stages has been dictated by the need for economy in watering. They are at first raised in shallow pans and then pricked out as soon as they show themselves likely to be healthy and vigorous. They are transferred to nine-inch pots when 6″ to a foot high, and these are arranged in wide trenches so that they can be watered all together by filling the trench (*cf.* p. 114). They are usually kept in the pots until about six months old and then some of them are already four or five feet high. The disadvantages attending this procedure was very clearly shown in the *Saretha* seedlings raised during the 1914-16 period. Owing to the very large number of healthy seedlings available, a set of one thousand were planted in rough ground, at one foot apart, when three months old. Another large lot were planted in pots in the usual manner and irrigated all together. Yet a further lot were retained for five months in their pans and then potted. Some hundreds were left in their pans and not even pricked out, while, lastly, a batch was planted in the ground when quite young, close together, being intended for the supply of failures in those raised in the pots. These separate lots of seedlings were examined and photographed at six months of age and varied, from six feet high, in those planted early in the ground close together, to 1—2 feet where left in the pans. The habit in all but one lot was fairly uniform and no classification was well possible according to this. Only those planted one foot apart in the ground showed habit differences well, and these varied from absolutely prostrate, through strongly oblique, by various stages, to nearly erect, besides showing other differences, such as in the shape and denseness of the plants.

VARIATION IN THE SUCROSE PERCENTAGE IN THE JUICE.

The chemical analysis of the juice of the seedlings and cane varieties is a heavy tax on the staff at disposal. Because of the incidence of most of this work at one time of the year, it was not thought necessary to attach more than one chemical assistant permanently to the staff of the Sugarcane Expert, but it will easily be gathered, from what follows, that this assistant is quite unable to deal unaided with the work during the period of stress. I am indebted to the Government Agricultural Chemist for generously placing two of his assistants at my disposal during the whole of the cropping season, thus making three altogether available for the chemical analysis of the canes.

The data obtained in the analysis of a seedling are as follows:—number of canes cut, weight of canes crushed in lbs., weight of juice obtained, percentage of juice to cane, Brix (corrected) per cent., sucrose per cent. in the juice, glucose per cent., glucose ratio and co-efficient of purity. For various reasons, in judging the value of a seedling, it has not been considered sufficient merely to make an analysis of the juice at harvest time. For one thing, the season is so long protracted, because of the number of analyses to be got through, that some of the seedlings would be heavily handicapped by this method, and, for another, time is available before harvesting commences to make a series of preliminary analyses to gauge the rate of ripening in the plots, so as to be able better to judge the date at which the final analyses should be made. The former series of analyses, made on one or two canes, is termed the "petty series" and the final analyses the "bulk," dealing as it does with what canes remain in each clump. There is little doubt that the seedlings of different parentage differ very considerably in their order of ripening, and the petty analyses give some idea as to the order in which the plots should be cut for final analysis.

The total number of analyses made since the foundation of the cane-breeding station (excluding preliminary soil analyses done by the Government Agricultural Chemist) are as follows:—

1912	Cane Juice	12	Others	52	(miscellaneous)
1913	,,	92	,,	43	(mainly well water)
1914	,,	2909	,,	33	(mainly chlorine determinations
1915	,,	400	,,	38	in cane juice)

In order to form an estimate of the relative richness of the juice in the seedlings, the plan usually followed in other countries was at first employed, namely, to consider the bulk analysis at crop time. But certain peculiarities in some of the curves obtained led to a full study of the whole series of bulk and petty analyses, and it was seen that to take the bulk alone into consideration might be misleading. For instance, during the 1914 harvesting season in order to test the ripening of the canes, certain of the *Naanal* seedlings were analysed once a fortnight, and the results are given in the table appended.

Fortnightly analyses of the juice in Naanal Seedlings (1912-14).

Madras No. 1411	Sucr.%	6·63	6·65	7·32	6·09	7·71	6·87	5·30	6·79	7·06	6·06	...
	Gluc.%	2·94	2·38	2·08	1·60	1·79	1·67	1·47	1·28	1·30	1·47	...
Madras No. 1439	Sucr.%	10·26	9·13	10·83	10·39	9·89	10·32	10·53	7·52	9·31	10·04	10·63
	Gluc.%	2·08	2·08	1·67	1·92	1·67	1·25	1·14	1·11	1·16	1·25	0·67
Madras No. 1454	Sucr.%	4·79	6·22	7·30	7·84	7·03	6·83	5·86	13·40	14·48	7·21	...
	Gluc.%	2·17	2·08	1·39	1·60	1·56	1·38	1·11	0·40	0·32	0·17	...
Madras No. 1474	Sucr.%	10·31	11·19	11·94	13·48	14·00	14·47	13·00	10·31	9·28	8·46	...
	Gluc.%	1·72	1·67	1·53	1·39	1·04	1·16	0·74	0·40	0·63	0·61	..
Madras No. 1490	Sucr.%	7·57	8·18	9·53	9·36	8·81	12·53	10·92	10·71	8·00	9·44	9·93
	Gluc.%	1·67	1·61	1·19	1·20	1·00	0·68	0·54	0·36	0·54	0·37	0·33

In all of these there is a steady fall in glucose percentage from start to finish. In Nos. 1411 and 1439 the sucrose varies little throughout the series, and a very fair idea would be obtained of the richness of the juice from the bulk analyses alone. In Nos. 1474 and 1490, on the other hand, there is a fairly steady rise in sucrose to a maximum, followed by a decline towards crop time, showing apparently that the canes were overripe when finally analysed in bulk. It is thus seen that the glucose determination alone is not sufficient to determine ripeness in a cane, as it continues to fall when the cane is overripe. The figures in No. 1454 show extraordinary variations, and no reliable opinion can be formed from them as to the normal richness of the juice. On the whole, it will be observed that the bulk analyses is not always a safe guide, and, after an examination of other cases, where petty and bulk analyses were available, it was finally determined to select, from the series of analyses of any seedling, that containing the highest reading of sucrose. In doing this, however, due regard has been paid to the percentage of glucose and the botanical description made at crop time. Where the former was unusually high or a note was recorded in the latter that the canes were immature or dried up and overripe, the analysis was rejected. After all, the main purpose of these analyses is to obtain a comparative figure of a seedling's merit, and it is felt that this will be best obtained by some such method as that adopted. It may perhaps give a rather high figure for the general richness of juice in the seedlings grown on the farm, but it is, again, thought

that this will be counterbalanced by the fact, illustrated below, (p. 155) that seedlings elsewhere have given better juice than on the farm itself.

In comparing the values of the juice of different seedlings, and in studying the correlations mentioned in the next section, at first the Brix, sucrose, glucose and co-efficient of purity were copied out and averaged. It was soon seen, however, that the excessive labour involved would materially restrict the work, and also that, usually, it would be sufficient to consider only the sucrose and glucose. Finally, even this was simplified and only the sucrose was averaged, care being taken to see that the glucose warning of immature canes was not neglected.

Comparison of sucrose in the juice in parents and seedlings, 1912-14.

	Parents				Seedlings			
	Number of analyses	Locality	Range of sucrose %	Average sucrose %	Number of seedlings analysed	Locality	Range of sucrose %	Average sucrose %
Chittan ...	5	Cane breeding Station.	15–18	16·67	500	Cane breeding Station	8–21	14·7
Karun ...	3	do.	15–18	16·02	345	do.	10–20	14·7
Kaludai Boothan	4	do.	14–20	16·78	60	do.	10–17	13·8
Saretha ...	5	Aligarh Farm 1913	13–17	14·59	51	do.	1–18	14·6
	15	Cane breeding Station	11–17	13·83				
	4	Wet lands, Coimbatore Central Farm.	18–19	18·91				
Cheni ...	12	Cane breeding Station	11–14	12·67	19	Botanic Garden, Coimbatore, 1913.	9–15	12·2
	5	Wet lands, Coimbatore Central Farm.	18	17·67				
	10	Mysore	16–19	17·01	16	Cane-breeding Station. 1914.	13–17	15·2
Poovan ...	5	Cane breeding Station	13–17	14·61	17	do.	12–20	15·0
Naanal ...	12	do.	9–16	12·36	180	do.	5–17	10·5
	3	Wet lands, Coimbatore Central Farm.	15–17	16·37				
Chin × ...	9	Cane breeding Station	12–16	13·81	18	do.	6–12	9·0
	7	Wet lands, Coimbatore Central Farm	15–18	17·30				
	7	North India	14–15	14·78				
Saccharum spontaneum		Cane breeding Station	3–5	4·00				
Shakarchynia ×	5	Cane-breeding Station	9–16	12·94	81	do.	6–13	9·8
	4	Sabour Farm (Taylor, 1911)	17	16·94				
Saccharum spontaneum		Cane-breeding Station	3–5	4·0				

In the accompanying table, details are given of the amount of sucrose in the juice of the seedlings of 1912-14 and of one lot of *Cheni* in 1911-13. It will be seen that there are considerable variations in the sucrose content of

seedlings of the same parentage. Thus, the *Chittan* seedlings varied from 8% to 21% and *Naanal* from 5% to 17%, and, generally speaking, the more analyses recorded in any one lot, the wider the range of the sucrose in the juice. There is also a definite relation between parents and offspring in this respect, the better parents producing the better seedlings. The analyses of the crosses are also interesting, in that they show that the sucrose in the seedlings approximates to the average of the two parents. In the other cases, of seedlings from parents not specially crossed, or "general collections," the average sucrose of the seedlings is generally lower than that of the parents, and this may be due to the fact, stated elsewhere, that it was not always possible to analyse a seedling at its optimum. Note must also be taken of the character of the land on the farm, for many varieties have given very poor results there. Thus, in *Cheni*, a Mysore cane, while ten analyses at Bangalore gave an average sucrose percentage of 17·01, twelve on the farm gave only 12·67, a figure more comparable with that in the seedlings. So also, *Shakarchynia* in Bihar gave 16·91, whereas on the farm it only reached 12·94. There is also a very marked difference in the results obtained on the Cane-breeding Station and on the heavy tank irrigated land on the adjoining Coimbatore Central Farm. The local canes, *Chittan*, *Karun*, *Kaludai Boothan* and *Pooran* also gave analyses a good deal lower in the seedlings than in the parents, but not sufficiently so as to suggest crosses with a wild Saccharum, of which, moreover, there was no trace in the morphological characters of the seedlings. In *Saretha* and *Chin*, there appears to be less difference between the juice anaylses collected from North India and those made at Coimbatore, suggesting that, for these canes at any rate, the conditions on the farm are fairly comparable with those in North India.

The prime object of the Cane-breeding Station is to raise new and hardy canes for North India, which will be capable of being grown in the fields under ryots' treatment and, in order to judge how seedlings raised at Coimbatore would behave in various parts of North India, some nine of the earlier seedlings of various parentage were distributed to Pusa, Shahjehanpur and Jubbulpore. It is unfortunate that analyses have only been recorded at the latter place, but seedlings have also been grown on the Central Farm wet lands and on different soils in the station itself. The accompanying table gives the sucrose and glucose in the juice of a set of seedlings grown outside the farm. From this table it will be seen that the seedlings respond readily to changes in soil and water, and there appears to be some probability that, in general, seedlings raised in the farm will, if anything, improve in the quality of their juice when grown elsewhere.

Comparison of the Juice of Seedlings grown under different conditions (all bulk analyses).

Seedling and its parentage	Garden land at Coimbatore (well irrigated)								Wet land in Central farm Coimbatore (tank irrigated) 1915		Adhartal farm Jabbulpore 1914-15		Notes
	Botanic garden 1913[1]		Cane-breeding station A 1914		Cane-breeding station B 1914		Cane-breeding station B 1915						
	Sucrose %	Glucose %	Sucrose %	Glucose %	Sucrose %	Glucose %	Sucrose %	Glucose %	Sucrose %	Glucose %	Sucrose %	Glucose %	
Madras No. 2. (Kaludai Boothan)	11·55	1·53	10·24	0·71	13·18	0·52	12·21	1·11	14·58	0·67	15·21	1·24	[1] First year seedlings grown in large pits filled with good soil but irrigated with brackish water.
Madras No. 6. (Poovan) ...	11·88	1·45	7·95	1·32	9·60	0·94	9·34	1·43	13·83	0·48	13·04	1·60	In 100,000 parts of water:—Total solids 239, injurious salts 165, sodium chloride 127.
Madras No. 11. (Poovan) ...	12·40	0·92		Failed.	13·64	0·65	16·09	1·10	17·26	1·00	...	...	A. Set plants grown first year from seedlings—in small pits filled with good soil; earth around saline; and irrigated at any rate at first with brackish water.
Madras No. 19 (Cheni) ...	11·43	0·22	12·89	0·86	12·64	0·65	13·26	0·48	16·75	0·10	12·74	1·12	In 100,000 parts of water:—Total solids 342, injurious salts 249, sodium chloride 189.
Madras No. 21. (Cheni) ...	12·36	0·16		Failed.	12·50	0·17	15·07	0·52	18·20	0·30	14·49	1·02	
Madras No. 25 (Cheni) ..	14·68	0·19	11·86	0·51	12·56	0·56	13·96	0·81	15·72	0·33	14·63	0·90	B. Set plants grown first and second years from seedlings—in smaller pits filled with good soil; earth around slightly saline: irrigated with sweet water.
Madras No. 29 (Cheni)	15·33	0·10	9·79	0·38	13·64	0·30	15·55	0·17	17·32	0·10	...	...	
Madras No. 45. (Cheni)	10·05	0·17	10·83	0·61	15·81	0·65	11·74*	0·67	17·78	0·29	14·71	1·02	
Average ..	12·30	0·58	10·59	0·73	12·95	0·55	13·40	0·79	16·43	0·41	13·13	1·15	In 100,000 parts of water:—Total solids 91, injurious salts 53, sodium chloride 33.
Average of five grown at all places	11·94	0·69	10·75	0·80	12·76	0·66	12·10	0·90	15·73	0·37	14·07	1·18	* 14·82 in petty analyses, therefore probably over-ripe.

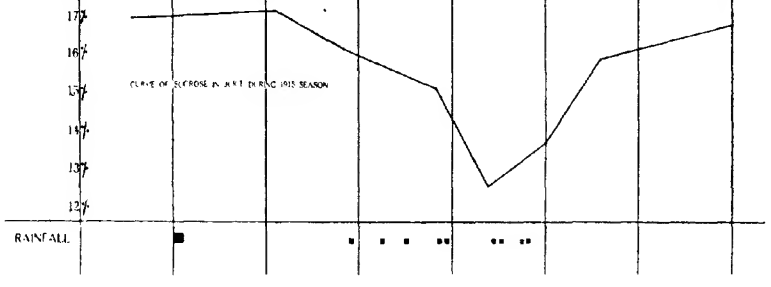
This varying behaviour of Madras seedlings grown in different localities raises the interesting question as to whether there is anything like it in ordinary cultivated canes. A good deal of attention has been given to this question and a number of analyses of certain cane varieties have been collected from different places. It is hoped that, in time, sufficient data will be accumulated. (1) to be able to forecast the probable behaviour of selected canes and seedlings when moved from one locality to another, and (2) to get a general idea of the suitability of different localities for sugar production in India.

The question as to the permanence of the juice characters of cane seedlings, when propagated as sets, is one of considerable importance and has been studied as far as data are available. Many of the 1911-13 seedlings were found to yield far better juice when planted in the second year from sets. But the seedlings had been planted in very large pits with good soil and their growth was in some cases very vigorous, and it is regarded as possible that this may have had a prejudicial effect on their ripening. Besides this, the great variations noted above in the richness of the juice in seedlings, when planted under different conditions, renders it unsafe to form conclusions from isolated cases. There is also another matter, already referred to, which may have an effect on the juice of seedlings when first analysed, namely the period of year at which they are cropped. Owing to the restricted arrowing season, the seedlings mature from June onwards, whereas the proper time for ripening canes in this locality appears to be much earlier in the year. Lastly, the weather also appears to have considerable influence on the character of the juice. The seedlings during the present (1915) harvesting season show this markedly, and much trouble has been caused by unseasonable rains. During the ripening season, usually a time of some anxiety as to whether any rain will fall, we had this year as much as 10 inches, and this appears to be reflected in the juice analyses, the cropping time being in general three months later than in the previous year. The canes in the varietal plots appear to have been practically ripe at the beginning of April but, after that, stimulated to renewed growth by the unusual rains, the sucrose percentage fell steadily, and it was not until the dry period in July-August that there was a sensible recovery. In these conditions the richness of the juice shown by the replanted 1912-14 seedlings suffered, and in many cases was not so high as in the first cropping season. The variations in sucrose in the juice are shown in the accompanying table, all the analyses in which were made up to dead leaf (*cf* p. 163). The series of analyses are spaced according to the part of the month in which they were made. Below, is an average of the sucrose in the four varieties chosen, with a curve to represent it graphically, while at the base is a series

Clump of Ketrai (Pansahi-like form) one year old, showing the presence of "early" and "late" canes. One of the former has a label attached, while a late cane is marked by a cross.

of dots indicating the falls of rain. There is a remarkable descent in the curve until the middle of June, after which recovery is rapid. Similar variations in sucrose content were met with in many of the seedlings, as shown by their petty and bulk analyses.

	FEBRUARY.	MARCH.	APRIL.		MAY.	JUNE.		JULY	AUGUST.
DATE OF ANALYSIS	19th		2–5th	24th	25th	11th	29th	16th	31st
JAVA	19·20		19·44	16·99	17·02	13·43	15·43	17·21	17·00
J 139	18·52		18·04	17·31	14·65	13·35	12·72	17·21	19·05
J 213	15·50		16·45	15·89	15·10	12·25	14·82	14·28	15·54
CHENI	14·57		14·62	14·28	14·18	12·02	12·34	14·78	15·47
AVERAGE	16·95		17·14	16·11	15·23	12·76	13·83	15·87	16·76



It is, thus, of obvious importance to get the seedlings as soon as possible into line with the local time of sowing and reaping, and to avoid these irregularities as far as may be. At present, after reaping them in June to August, they are planted in beds and will ripen about a year later. But, in future, cuttings will if possible be taken from the young canes in February and these will be planted in the ordinary varietal plots, which have been hitherto, for one reason or another, planted late each year. According to this arrangement, the seedlings collected, say, in December 1915, will be first analysed in June 1917, the second analysis being in February 1919. These dates throw a side light on the length of time required for a seedling to be tested, the 1919 analysis being by no means the latest one necessary before forming an opinion as to its value. An additional advantage of this February planting will be that sets will be available for distribution to North India at the usual planting time there.

As in the case with cane varieties, extraordinary variations have been met with in a seedling, in analysing the different canes in the clump. This has led to increased care in sampling. For petty analyses, the canes chosen are

as far as possible without any rooting or shooting, and are such as would develope into healthy canes at crop time. Those which are abnormal in any way are rejected, and the same precaution is taken at crop time, the idea being to try and obtain such results as would be given by a mass of healthy, well-grown canes. But, besides this, attention has been paid during the past season to the fact, pointed out in the recently published Memoir on Punjab Canes,[1] that, in some varieties, there are usually two kinds of cane in each clump, differing not only in certain morphological characters, but also in the time of origin and therefore in age. In the paper referred to, there was no opportunity of testing the chemical character[2] of the juice of these two classes of canes (termed "early" and "late"), but this has been observed during the current (1915) cropping season. The results of this study, carried out at my request by Mr. T. S. Venkataraman on some of the varieties growing in the Cane-breeding Station, are detailed below. It will be seen that they agree closely with those obtained in the Punjab case, in that this peculiarity (of two classes of canes being present at crop time) is confined to certain varieties of canes and is not appreciably present in others, suggesting a profound difference in the mode of formation of the branches, a subject which is receiving further attention. As detailed in the paper referred to, the early canes are characterised by commencing with short, narrow joints which gradually increase in length and thickness upwards, whereas the late canes commence with long joints of full thickness which are succeeded by others which become shorter and thinner upwards. This has been our main criterion, and another character of the early and late canes has also come out strongly, in that the early canes have many joints while the late ones have few. Mr. Venkataraman has found that the cane varieties examined on the farm may be divided into the following two classes as regards the formation of early and late canes in each clump.

(1). Varieties in which early and late canes can be separated easily. It would appear that in these varieties there is a continual production of canes, which may be divided into early, intermediate, and late. To this class belong *Pansahi*, *Chynia*, *Yuba*, *Maneria*, *Sanachi*, *Kahu* and the *Pansahi*-like *Ketari*, all of them belonging to the *Pansahi* group of *Ganna* canes of North India. A photograph of *Ketari* is appended in which the differences between early and late canes can be clearly seen (Pl. XXIX). Taking the length of the lowest joints as the criterion, we find a close relation between this

[1] Barber, *Ibid* p. 38. *et seq.*
[2] *Ibid*, p. 41.

character and the average number of joints developed, as will be seen from the following table:

Average number of joints in early and late canes.

	Early Cane		Late Cane	
	Number of canes examined	Average number of joints	Number of canes examined	Average number of joints
Maneria	14	36	10	20
Yuba	12	33	12	19
Pansahi	2	31	2	24
Kahu	1	38	4	21

The next table gives the chemical analysis of the juice in early and late canes. The samples have been taken in two ways. Those termed "ryots' sample" refer to the whole cane with such part of the young shoots cut off as is done by the ryot when milling. "Dead leaf" means that only the lower part of the cane has been taken, namely, that portion which bears dead leaves, the cane being cut at the point where the highest dead leaf springs from the stem.

The character of the juice in early and late canes.

Variety	Date of planting	Date of analysis	Kind of sample	Class of cane	Number of canes tested	Sucrose %	Glucose %	Co-efficient of purity
Maneria (all from one clump).	2nd June 1914.	19th May 1915.	Ryots'	Early ..	5	11·30	0·77	74·69
			,,	Late ..	2	9·52	0·52	69·40
Maneria (from the whole row).	2nd June 1914.	21st May 1915.	,,	Early ..	9	10·27	0·91	73·6
			..	Intermediate.	10	9·99	0·85	73·2
			,,	Late ..	8	7·24	1·35	60·2
Yuba (all from one clump).	2nd June 1914.	21st May 1915.	,,	Early ..	6	10·61	1·09	72·0
			,,	Late ..	6	7·84	1·19	62·4
			Dead Leaf.	Early ..	6	11·22	0·91	74·8
			,,	Late ..	6	9·83	0·78	70·6

The table shows us that it is necessary to exercise caution in taking samples of these varieties. If the classification of canes into early and late is neglected, great differences in sucrose are likely to be met with in taking successive canes from the same clump, and the known irregularities in this respect are likely to be intensified.

(2). Varieties in which the separation of early and late canes is difficult or impossible. These varieties appear to form their canes up to a certain period and then cease. *Baroukha* (Sabour), *Ekar* and *Kaghze* may be taken as types. In these, although it was not found easy to separate early and late canes in the clump, the attempt was made according to the length of the basal joints, with the following results, as regards the total number of joints in the canes.

Baroukha, number of joints in all the samples analysed on 31st May		32, 33, 32, 30.
Kaghze,	do	35, 36, 34, 34, 33, 35.
Ekar,	do	35, 37, 37, 36, 39, 37.

There is no separation here into few and many jointed canes in the clump.

The analysis of the juice in these canes is given in the table

Attempted separation into early and late canes.

Variety	Date of planting	Date of analysis	Kind of sample	Class of cane	Number of canes tested	Sucrose % in the juice	Glucose % in the juice	Co efficient of purity
Baroukha	5th June 1914	17th May 1915	Ryots'	Not classed ..	15	9·91	0·56	72·5
		31st May 1915	,,	Early? ...	2	9·38	0·50	71·1
			,,	Late? ...	2	9·27	0·45	71·4
			Dead Leaf.	Early? ..	2	10·72	0·50	75·5
			,,	Late? ...	2	10·62	0·33	75·9
Kaghze	1st June 1914	15th May 1915	Ryots'	Not classed	15	9·46	1·56	69·3
		31st May 1915	,,	Early? ...	2	12·01	0·77	77·4
			,,	Intermediate?	2	12·39	1·14	76·4
			,,	Late? ..	2	11·66	1·00	75·2
			Dead Leaf.	Early? ...	2	11·15	1·04	76·9
			,,	Intermediate?	2	12·81	0·71	82·0
			,,	Late? ...	2	12·86	0·68	79·8
Ekar ...	5th June 1914	17th May 1915	Ryots'	Not classed ...	14	12·80	0·59	78·7
		31st May 1915	,,	Early? ...	2	12·79	0·33	78·6
			,,	Intermediate?	2	12·46	0·46	78·9
			,,	Late? ..	2	12·34	0·33	78·7
			Dead Leaf	Early? ...	2	13·74	0·37	81·3
			,,	Intermediate?	2	12·77	0·24	81·4
			,,	Late? ...	2	13·68	0·31	81·5

There is no trace of the different classes as regards cane juice, met with in the *Pansahi* group. These varieties thus will present comparatively little difficulty in sampling, as far as regards class of cane, and it is probable that many of the thick canes resemble them in this character.

There is no doubt as to the great improvement in the character of the seedlings grown on the farm in each successive season. The accompanying table gives the general average of the sucrose content in each lot of canes raised in 1913-15, which may be compared with the table on p. 153 of the 1912-14 results. From a perusal of the list of canes used as parents (*cf.* section on Enumeration of Seedlings), it will be gathered that this improvement is mainly due to the higher class of the latter.

Average % of sucrose in the juice in the 1913-15 seedlings.

Variety	Number of seedlings analysed	Sucrose % in the juice: Range of variation. The middle figure indicates the maximum in the curve	Sucrose % in the juice: Average	Remarks
Karun Gen. Coll.	59	7—13—19	13·3	
Do. Selfed	12	8—12—18	13·6	
Chittan Gen. Coll.	74	6—13—20	14·3	
Kalndai Boothan Gen. Coll.	204	7—16—21	15·3	
Vellai × *Sacch. Narenga*	95	6—12—17	11·5	
Do. × Ashy Mauritius	87	9—16—22	15·9	
Do. × Karun	22	11—17—20	16·6	
Do. × Striped Mauritius	12	11—17—20	16·2	
Do. × Fiji C	72	8—13—20	15·0	
Do. × Chittan (1)	...	...	...	(1) These batches consisted of very few seedlings analysed and have been omitted.
Do. × M. 1354	22	7—12—16	10·9	
Do. × M. 1464	13	9—11—16	11·2	
Do. × M. 1428	20	10—13—15	12·6	
Poovan Gen. Coll.	14	12—15—20	15·9	
Do. Selfed (1)	...	...	...	
Java (Hebbal) Gen. Coll.	138	13—19—21	17·7	
B 208 Selfed	50	12—18—20	17·4	
Do. Gen. Coll.	59	11—18—23	17·6	
Striped Mauritius (Hebbal) Gen. Coll.	127	12—16—21	16·5	
Do. (Central Farm) Genl. Coll				
Do. do. Selfed (1)	...	...	...	
White Mauritius Gen. Coll.	21	12—17—20	16·6	
Do Selfed (1)	...	...	...	
Red Mauritius (1)	...	...	...	
Green Sport of Striped Mauritius	59	13—17—22	16·9	
Red Sport of Striped Mauritius	14	11—17—19	16·6	
Fiji B (1)	...	...	...	
Fiji C Selfed	20	13—16—20	15·5	
Fiji C Gen. Coll. (1)	...	...	...	
Ashy Mauritius (Central Farm) Gen. Coll.	31	11—15—21	16·2	
Do. do. Selfed	38	12—17—20	16·5	

Taking the whole series of *selected* seedlings during the past three seasons we see that the sucrose in the seedlings has steadily risen, as follows :—

Sucrose in the juice of selected seedlings.

	Number of seedlings grown	Over 17%	Over 18%	Over 19%	Over 20%	Over 21%	Over 22%	Over 23%	Remarks
1911—13 (Over 17%) ..	48	2	..	..	..	..	..	..	All the seedlings were grown on.
1912—14 (Over 17%) ...	2,068	95	40	9	2	...	...	...	The standard of selection, 17% sucrose in the juice and over.
1913—15 (Over 18%) ...	2,400	400	128	101	22	3	1	1	The standard of selection, 18% sucrose in the juice and over, together with vigorous growth.

But it is a question whether the extremely high sucrose content attained is altogether in accordance with the ultimate aim of the Cane-breeding Station. Although high sucrose is an undoubted gain. the question as to whether the canes giving this will succeed in North Indian conditions is altogether another matter, and can only be determined after long series of experiments. On the face of it, it does not appear likely that rich canes of exotic parentage will be the best for North India, and it will, therefore. be even an advantage if the general level of sucrose content be lowered, if this implies the greater infusion of North Indian parentage. During the 1914-16 season every effort was made to obtain seedlings of this character. But, of the multitude of crosses attempted, comparatively few have succeeded, owing to the sterility or ill-timed emergence of the North Indian arrows and, in their place, a large number of seedlings have been raised from *Saretha, Chin, Pansahi* and other Indian parents, pure and simple. This will mean the lowering of the general average of sucrose in the juice during the next season, but the results are, perhaps, more likely to be of ultimate value than when, as in the 1913-15 season, comparatively few North Indian canes appeared among the list of parents. As stated elsewhere, the aim which is steadily held in view is to secure crosses between the best North Indian canes, such as *Saretha, Pansahi, Mungo, Chin*, and richer, thicker, tropical canes, and the arrowing plots have been laid down with this object in view.

There is no doubt that, but for the timely assistance of the Government Agricultural Chemist, in lending the service of two of his assistants during crop time, progress would have been comparatively slow. But, even as it

is, the completion of the seedling analyses in the limited period of ripening is an extremely difficult matter, and many seedlings suffer from not being analysed at their optimum. An innovation has been introduced in the petty analyses during the 1915 cropping season, which promises to quicken up the work in future. On going through any batch of seedlings for the first time, it is considered sufficient, in the place of the full petty analysis, merely to take the Brix reading of the juice, and at once to pass on to other seedlings if this does not reach a certain figure. This, it is claimed, will give a fair indication both of the ripening and of the relative value of the seedlings. Further, relying on the theory of phytomers, whereby each segment of a plant with its leaf or leaves is considered to be a more or less independent part,[1] an attempt has been made with some success to get an early indication of the ultimate value of a seedling by analysing some of the lower, apparently mature joints. The limiting joint thus far chosen has been the highest in which the attached leaf has completely withered. It is a question as to what further changes take place in the juice contained in such a joint, but the joints of the canes are very clearly separated from one another by their internal structure, and it is difficult to see how the juice in them will undergo great changes after the supplying leaf has died. The results obtained are on the whole suggestive, and there seems to be some promise, on the adoption of the analysis of the cane up to the highest dead leaf, of obtaining early indications as to which seedlings are worth going on with. If the method proves to be fairly satisfactory, it will be possible to rule out in any batch a large number of inferior seedlings and thus save much time in the final analysis.

[1] This must not be taken too literally and is perhaps more of a morphological than a physiological conception. That neighbouring joints in a *growing* cane are without influence on one another is very unlikely, and this lack of independence has been strongly brought out by J. Kuijper in his paper "Is een blad met un internodium bij het riet als un physiologische eenheid op te vatten"? *Med. Proefst. v. d. Java-Suikerindustrie.* Deel V. No. 15, 1915.

CORRELATIONS BETWEEN MORPHOLOGICAL CHARACTER OF SEEDLINGS AND THE RICHNESS OF THEIR JUICE.

The correlations thus far studied at the Cane-breeding Station are based chiefly on the characters of sugarcane seedlings of the 1912-14 period, and must be regarded as an introduction rather than as a piece of completed work. The data were unsatisfactory in many minor points, and it is hoped that further work will follow as new series are subjected to the necessary tests. The 1912-14 seedlings were examined at crop time according to a prepared scheme and, although it was found necessary, during the examination, here and there to alter certain of the particulars, thus destroying continuity in some characters, sufficient data were accumulated for averages to be struck, especially in the larger batches of seedlings. The heavy descriptive work was under the charge of my Botanical Assistant, Mr. T. S. Venkataraman to whose energetic persistence I am greatly indebted.

The correlations observed, although sometimes very distinct, do not exclude very considerable irregularity in each series. This is not to be wondered at when the conditions have been noted. The recorded results are at best approximations, as has been fully conceded in the sections on variations among the seedlings in morphological and other characters. The chemical analyses used, again, are the highest observed during petty and bulk tests; they are probably, in many cases, not a very accurate gauge of the comparative richness of the juice and will, to a certain extent, be influenced by the number of analyses taken of any particular seedling. Even then it was found advisable ultimately to concentrate attention only on the sucrose contained in the juice, merely noting the glucose in order to rule out obviously unripe specimens. The detailed botanical descriptions were also largely consulted in order to eliminate those seedlings which were abnormal in their growth and either immature or overripe. The morphological characters were carefully observed, but the seedlings were of unequal growth at crop time, there were a very large number to be dealt with and the time of the staff available was strictly limited. Our knowledge of the parentage of the seedlings was also

incomplete, and it is possible that some of the irregularities noted may be due to the presence of crosses in the general collections.

The following is the list of seedlings examined :—

(1) 1911-13. A small lot of *Cheni* seedlings (about 18) which were very carefully studied, but were grown under somewhat abnormal conditions.

(2) 1912-14. About 500 *Chittan* seedlings, over 300 *Karun*, 50 *Kaludai Boothan* and 13 *Pooran*, all general collections in the field, that is without any knowledge of possible local crossings: 50 selfed *Saretha* seedlings and 65 crosses between *Shakarchynia* and *Saccharum spontaneum*.

(3) 1913-15. About 80 crosses between *Vellai* and *Saccharum Narenga*.

These seedlings were studied with regard to the following possible correlations. The leaf width at maturity was compared with the sucrose in the juice, with the thickness of the cane, the total weight of the seedling and the number of canes and shoots, as indicating tillering power. Other characters compared with sucrose were the length of leaf, the leaf module (length divided by width), thickness of cane, length of cane and cane module (length divided by thickness), and colour of cane. In a number of these comparisons a distinct correlation has been observable, but it is important to remember that this does not mean that a uniform series was obtained. The greatest variations occurred in all the series, and it was only on taking them as a whole and dividing them into classes, that the tendency was definitely established. While, for instance, the general tendency is for narrow leafed seedlings in any series to have richer juice, this does not preclude the occasional occurrence of excellent seedlings among the broader leafed classes. It is possible that these irregularities may be due to faults in analysis or in observation, as suggested above, but they may be intrinsic, and we have at present no means of determining their cause. Naturally, the greatest reliance is placed on the larger series (*Chittan* and *Karun*) and it is not certain what is the lowest number of seedlings in which true correlations may be expected. Probably this varies with the different characters under consideration but, taking the whole series of observations, it is considered that 40 or 50 seedlings will usually be sufficient, but that smaller numbers than these are liable to errors, which, however, can usually be detected on inspection by the occurrence of isolated abnormal seedlings in their wrong place. This has been easily observable in the small *Poovan* lot, where one seedling, with 20·40% sucrose in the juice, towered above the rest and, to a certain extent, dominated the results according to its position.

In order to make the general method of calculation clear, it has been thought advisable to give the details of one correlation studied, and I have

selected, at random, that between leaf width and sucrose in *Karun* seedlings, and I have gone into this in some detail in order to indicate some of the difficulties encountered in the work. Arranging the whole 322 *Karun* seedlings in order of leaf width, it was found that they fell into 20 classes differing from one another by one-tenth of an inch, and ranging in width between 1·5″ and 3·6.″ The best sucrose reading obtained in petty or bulk analysis was placed opposite each seedling and averages were struck for each class of common leaf width. The following was thus obtained :—

Leaf width and sucrose in Karun seedlings.

Leaf width	No. of seedlings	Total sucrose in the juice	Av. sucrose per seedling
1·5″	1	15·69	15·69
1·6″	3	48·78	16·26
1·7″	3	49·25	16·42
1·8″	12	182·39	15·20
1·9″	9	69·42	15·21
2·0″	20	299·23	14·96
2·1″	35	532·15	15·20
2·2″	37	542·58	14·66
2·3″	41	621·20	15·15
2·4″	34	509·29	14·93
2·5″	37	537·29	14·52
2·6″	28	412·60	14·74
2·7″	25	379·37	15·17
2·8″	11	167·92	15·27
2·9″	12	171·45	14·29
3·0″	6	91·82	15·30
3·1″	4	51·46	12·86
3·2″	2	27·76	13·58
3·3″	1	12·36	12·36
3·6″	1	10·64	10·64

The figures in column 2 of the table present together a fairly normal frequency curve (*cf.* p. 142), and it may be noted that in column 4 the higher sucrose values are more or less collected in the upper half of the table. But the importance of these values in the general average is regulated by the number

opposite to each in column 2, namely, the number of seedlings having that sucrose reading, and, in order to see the general tendency, it is necessary to contract the series of classes considerably. The whole have accordingly been collected into four and two classes, and this has been done in two different ways.

(1) The list has been arranged in four (and two) equal classes, these classes having the same number of seedlings in order of leaf width. The following classes are thus obtained :—

Classes		Number of seedlings	Range of leaf width	Total sucrose in the juice	Average sucrose
Four equal classes (as regards numbers)	1	80·5	1·5″—2·1″	1,226·29	15·24
	2	80·5	2·1″—2·3″	1,201·78	14·94
	3	80·5	2·4″—2·6″	1,186·61	14·74
	4	80·5	2·6″—3·6″	1,185·35	14·73
Two equal classes (as regards numbers)	1	161	1·5″—2·3″	2,428·07	15·08
	2	161	2·4″—3·6″	2,371·96	14·73

(2) The list has been arranged in four (and two) classes, this time separated by equal differences in leaf width. The four classes obtained in this way are of unequal size, the first and last being smaller, that is, having fewer seedlings in them than the second and third. The value of this classification will obviously depend on whether the end classes are sufficiently large for fair averages to be obtained.

Classes		Number of seedlings	Range of leaf width	Total sucrose in the juice	Average sucrose
Four classes according to differences in leaf-width	1	48	1·5″—2·0″	732·14	15·25
	2	184	2·0″—2·5″	3,041·74	14·91
	3	82	2·6″—3·1″	1,274·62	14·82
	4	8	3·1″—3·6″	102·22	12·78
Two classes	1	232	1·5″—2·5″	3,474·65	14·98
	2	90	2·6″—3·6″	1,325·38	14·73

In dividing the 322 *Karun* seedlings into equal classes according to numbers, a fraction is introduced, and this becomes more inconvenient if it is $\frac{3}{4}$ instead of $\frac{1}{2}$, as it would be if there were 321 seedlings instead of 322, and it has been usually found simpler, when the total number of seedlings is not divisible by four, to allow the classes to overlap, this being done symmetrically. Thus, if there were 321 seedlings, each of the classes would be made to overlap one, that is, the last of the first class would be repeated and taken as the first of the second class, and so on. There would thus be three seedlings repeated and we should have four classes of 81 each. Similarly, when there are 322.

the first and second classes and the third and fourth would overlap and, when there are 323, the second and third only, in each case bringing the classes each to 81 seedlings. This method does away with the fraction which introduces difficulties in calculation and, in dealing with large numbers, has no advantage. By using the method of overlapping, in classes of equal numbers there will never be an excess of seedlings over the actuals of more than three.

In the second method, that of dividing the list into classes with equal differences in leaf width, on the other hand, the matter is not so simple. If overlapping is resorted to, it will not be of individuals but of *classes* and the number of seedlings will sometimes be considerably increased, according to the numbers in the repeated classes. The number of classes in the general list of *Karun* seedlings is 20, but we cannot simply divide these into four classes of five each because they are not of equal leaf width differences. The extremes are 1·5″ and 3·6″, thus making 22 classes separated by one-tenth inch in leaf width, the two classes 3·4″ and 3·5″ having no representatives. In dividing these into four classes according to leaf width, two must overlap, giving the four groups 1·5—2·0″, 2·0—2·5″, 2·6—3·1″ and 3·1 -3·6″. It is obvious that there are objections to this overlapping, but the method appears, on the whole, to work satisfactorily. The two classes which are repeated have, between them, 24 seedlings, and the number of seedlings in the four classes is thus 346 instead of the correct number 322. It all depends on whether the repeated classes are likely to alter the general results, and this is one reason for the inclusion of the division into two classes as well, for then the class repeated, if there is one, will be a different one. In the case in point, class 2·0″ (with 20 seedlings) has 14·96 sucrose, which is fairly average, but class 3·1″ (with 4 seedlings) is distinctly low, but there are too few seedlings in the latter class to make much difference. Each case must be thus judged on its merits, and one is given on p. 189, where the repetition of classes has introduced a discrepancy, because the classes repeated are both exceptional and of sufficient size to influence the results. This is at once checked by the divisions into two classes and such cases give additional weight to the advisability of studying these correlations by the two methods described above.

From a consideration of the table of *Karun* seedlings, it is seen that there is a distinct tendency for the narrow leafed forms to have richer juice (as judged by the sucrose contained) than the broader leafed forms, in other words, that there is a negative correlation between leaf width and sucrose. But this by no means excludes the occurrence of good seedlings among the

broad leafed plants. Taking the whole series of seedlings and selecting the five best and five worst seedlings, we have the following :—

	No. of seedlings	Leaf width	Sucrose % in juice	Glucose % in juice
The five *Karun* seedlings with highest sucrose ...	907	1·9″	19·85	0·13
	973	2·1″	19·28	0·71
	1,199	2·3″	19·09	1·35
	1,098	2·2″	19·07	0·50
	1,033	2·7″	19·01	0·93
The five *Karun* seedlings with lowest sucrose ...	1,278	2·2″	10·31	1·16
	952	3·6″	10·64	1·56
	1,130	1·9″	10·74	1·43
	998	1·8″	10·81	2·00
	1,039	2·2″	10·86	2·17

These figures are interesting in several respects and deserve careful consideration. The average leaf width of the whole series of *Karun* seedlings is 2·4″ and, if we exclude, in selection, all seedlings with wider leaves than this we may lose a very good one, for instance No. 1033. On the other hand, the seedling with narrowest leaves in these ten has only 10·81% sucrose. The glucose in the low sucrose class is much higher than in the high sucrose class, as might have been expected, but it is a question whether some of the former have not been hardly treated, in that they may have been unripe at crop time. Lastly, the seedling which had the widest leaves in the whole 322 seedlings, No. 952, and which had received marked attention throughout its growth because of this, was lowest of all but one in sucrose, and all the seedlings with widths over 3·0″ were very poor. This is an example of a fact not infrequently recurring in these studies, namely, that a seedling which differs markedly from the rest is often of very poor character as regards its juice. The extremes in any series, chiefly such as are of unusually large dimensions are generally more or less worthless.

As I have stated above, the selection of this correlation in the *Karun* seedlings for detailed analysis was made purely at random, and facts similar to those here noted may be met with in any of the larger series dealt with in the paper. It is hoped that discrepancies such as those noted may be ruled out by more careful selection, as regards growth and maturity, in the further sets of seedlings as they reach the stage when chemical analysis is possible, but there is no disguising the fact that irregularities are bound to occur, however much care is thus taken.

LEAF WIDTH AND SUCROSE.

Correlation 1.

The correlations thus far investigated will now be dealt with in succession, commencing with that between leaf width and sucrose. It is a well recognised fact that, while more or less profound differences in the floral organs are found necessary for the classification of plants, it is to the minute differences in the vegetative organs that the plant breeder looks for indications of character. Small differences in the width of leaves otherwise entirely similar, fall under the latter category. These are easily marked in any batch of seedlings and, from the fact that the broader leafed forms more nearly approach the thicker, richer, tropical canes, they have attracted attention from the very beginning. Between 1,100 and 1,200 seedlings have now been measured for leaf width at crop time. In growing plants, as has been stated above, probably the best method of determining the average width of the leaves in any seedling is to observe the general appearance of the plant at a short distance, and then to measure what appears to be an average leaf carefully. This method is called "eye measurement," but, at maturity, it has not been found possible to apply it. The plants have grown too high for accurate judgment and the leafy shoots are frequently battered by the weather. The following method has accordingly been adopted. Ten healthy shoots are cut and laid out. In each of these the broadest leaf is selected and measured at its broadest part, and an average is then struck between the ten measurements obtained. The factor here dealt with is therefore less the average leaf width than the maximum, the greatest leaf width of the seedling at crop time. The method of dividing the seedlings into classes has been described in detail for the *Karun* series and, in the table appended, summaries are recorded for all the batches of seedlings measured. In this and the following correlations the classes are arranged in ascending order, commencing with narrowest, shortest, thinnest, etc., and passing regularly to the widest and so on. *Chittan, Karun, Kaludai Boothan, Saretha* and *Cheni* agree in showing a very distinct negative correlation between leaf width and sucrose in the juice. In the small class of *Pooran* seedlings, this correlation is reversed, because of the errant position of the

single seedling, No. 1810, with 20·40% sucrose. It might be considered better to avoid the inclusion of this series in the tables that follow, but it has been retained in order to help us in judging the lower limits of numbers which can be safely employed, and the nature of the error met with in dealing with very small numbers.

These are all general collections in which the father is not definitely known. The *Naanal* seedlings, also a general collection, do not fall into line, although some seventy in number. In fact, the correlation, although somewhat irregular, is distinctly positive. A tendency in the same direction is traceable in *Vellai* × *Saccharum Narenga* and, to a less extent, in *Shakarchynia* × *Saccharum spontaneum*, all the members of which two series are undoubted crosses. This fact tends to support the suggestion that the *Naanal* seedlings of 1912-14, purporting to be a general collection, may be comprised, to a certain extent, of crosses, some of which show a strong resemblance to *Saccharum spontaneum*. It is also, however, worth noting that the general series, with the probable exception of the small *Cheni* class, are thick canes, whereas *Naanal* is an indigenous Indian one, the only one besides *Cheni* belonging to this class in the seedlings measured. It is, namely, possible that the thicker tropical canes differ in these correlations from the Indian canes. Be that as it may, the difference in behaviour between the general collections and the crosses is interesting and will be met with in several other cases. It has suggested itself that the deviation of the *Naanal* results, from those obtained for *Karun*, *Chittan* and other general collections, might be caused by the inclusion of the six aberrant forms noted on page 134, as all of them had markedly low sucrose content and very narrow leaves. Figures have accordingly been prepared for the *Naanal* seedlings in this and other tables in two ways, firstly, by taking all the seedlings and, secondly, by eliminating the six seedlings resembling *Saccharum spontaneum*. The general results in the two sets of correlation figures obtained are, however, more or less similar.

	Number of seedling	[1]Equal classes as to numbers of seedlings						[1]Classes of equal differences in leaf width						Correlation
		Two classes		Four classes				Two classes		Four classes				
Chittan	492	[2]14·89 249	14·42 243	14·94 125	14·84 124	14·55 124	14·29 119	14·80 293	14·43 199	15·33 37	14·74 256	14·50 162	14·13 37	−
Karun	322	15·09 161	14·73 161	15·24 80·5	14·94 80·5	14·74 80·5	14·73 80·5	14·98 232	14·73 90	15·25 48	14·91 204	14·82 86	12·78 8	−
Kaludai Boothan ...	57	13·98 28	13·38 29	14·57 14	13·40 14	13·78 15	12·99 14	13·77 31	13·60 25	14·66 7	13·51 24	13·80 20	12·78 5	−
Saretha	44	14·88 22	14·16 22	15·34 11	14·42 11	14·07 11	14·26 11	15·17 28	12·79 16	15·40 6·5	15·07 21·5	13·70 13·5	12·95 2·5	−
Saretha (Leaf-width judged by eye.)	48	14·81 24	14·15 24	15·17 12	14·56 12	14·21 12	14·09 12	...	...	...	...	...	...	−
Cheni	16	13·04 8	11·83 8	...	...	...	...	12·9 10	11·6 6	...	...	...	...	−
Poovan	12	15·17 6	16 85 6	...	...	...	...	15·23 8	15·85 4	...	...	...	...	+
Naanal (all)	71	10·30 36	10·91 36	9·67 18	10·94 18	10·90 18	10·93 18	9·77 ...	10·91 ...	8·97 6	10·45 19	10·90 40	10·95 6	+
Naanal (*Saccharum spontaneum* class left out.)	65	10·58 34	10·92 34	10·14 17	11·03 17	10·90 17	10·94 17	10·45 22	10·92 43	9·85 9	10·87 13	10·99 37	10·46 6	+ ?
Shakarchynīa *Sacch. spont.*	62	9·68 31	9·69 31	9·74 16	9·61 15	9·73 15	9·66 16	9·64 31	9·69 31	9·80 8·5	9·58 22·5	9·70 26	9·65 5	0
Vellai × *Sacch. Narenga*	81	11·52 42	11·88 42	11·47 21	11·57 21	11·90 21	11·87 21	11·24 40	11·81 54	11·40 11	11·18 29	11·89 39	11·61 15	+ ?

[1] The classes in this and the following tables are arranged in ascending series, commencing with the lowest measurement figure of the character being compared with sucrose.

[2] The upper figure indicates sucrose in the juice, the lower figure the number of seedlings in the class.

LENGTH OF LEAF AND SUCROSE.

Correlation 2.

This correlation calls for little remark. The length of leaf was obtained in exactly the same manner as the leaf width, in fact the same shoots were measured in the two cases. In all the classes examined, excepting one, there is a distinct negative correlation between leaf length and sucrose in the juice. The exception is the cross between *Vellai* and *Saccharum Narenga*, again a series of crossed seedlings. The absence of divisions into four classes in the smaller series is due to great irregularities in these, the full lists of seedlings arranged according to length of leaf, not falling readily into normal frequency curves as they did in the leaf width series.

	Number of seedlings	Equal classes as to numbers of seedlings						Classes of equal differences in length of leaf						Correlation
		Two classes		Four classes				Two classes		Four classes				
hittar ...	491	14·87	14·43	15·01	14·73	14·46	14·41	14·86	14·44	14·65	14·88	14·51	14·42	–
		245	246	123	122	123	123	276	244	26	250	216	26	
Karur	324	15·01	14·79	15·21	14·81	14·99	14·59	15·08	14·68	15·31	15·01	14·69	14·64	–
		162	162	81	81	81	81	203	159	52	151	137	22	
Kalndai Boothan ...	57	14·25	13·09	...	...	...	...	14·09	13·03	...	...	...	...	–
		29	29	...	...	...	...	35	22	...	..		...	
Sarotha	48	14·97	14·18	.	..	...	...	15·08	14·33	...	..	...	...	–
		24	24	...	...	...	...	15	33	...	..	..	..	
Cheri ...	15	12·34	12·03	..	..	..	.	...	...	...	..	...	..	–
		8	8	..		..	.		...	...	...	...	...	
Peovar	13	15·64	15·13	.	..	..	..	...	...	..	...	...	...	–
		7	7		...	...	.	...	.	...	...	...	.	
Vellai *Sacch. Narenga*	81	11·45	11·84	11·49	11·41	11·96	11·72	12·10	11·62	12·57	11·83	11·51	11·80	0
		42	42	21	21	21	21	11	70	4	7	43	27	
Naanal (*Saccharum spontaneum* class left out.)	65	11·09	10·45	.	...	...	...	11·09	10·45	.	.	...	...	–
		32	33	...	...	...		32	33	.	...	...	...	
Naanal (all)	71	10·96	10·24	..	...	...	...	10·98	10·24	...	...	.	..	–
		36	36	..		...	.	35	36	...	.	...	...	

LEAF MODULE AND SUCROSE.

Correlation 3.

The leaf module, as explained in the section on Variation in Morphological Characters, is the average extreme leaf length divided by the average extreme leaf width, a factor noted in a previous paper[1] as of some value in distinguishing North Indian canes. In the general collection series there is a distinct positive correlation between leaf module and sucrose. The series is however marred by the *Karun* seedlings, where the curve is irregular, owing to the high sucrose content in two classes early in the list, and there is thus only a tendency towards a positive correlation. The crosses again agree in differing from the rest, which is not surprising, in that the present correlation is a combination of the two previous ones. *Naanal* also shows a distinctly negative tendency.

[1] Barber, C. A. *Mem. Dept. Agri. India, Bot. Ser.* vol. VII, no. 1, p. 31

LEAF MODULE AND SUCROSE.

	Number of Seedlings	Equal classes as to numbers of seedlings						Classes of equal differences in leaf module						Correlation
		Two classes		Four classes				Two classes		Four classes				
Chittan	466	14·62	14·98	14·49	14·76	14·90	15·06	14·67	14·98	14·38	14·72	14·95	15·20	+
		233	233	117	116	116	117	324	196	46	278	173	23	
Karun	324	14·90	14·92	15·07	14·74	14·83	15·01	14·89	14·94	13·89	14·99	14·85	15·39	+ ?
		162	162	81	81	81	81	181	142	17	164	118	24	
Kalndai Boothan ...	55	13·48	14·09	...	..	...	...	13·48	14·09	...	...	...	...	+
		28	28	...	...	...	...	28	28	...	...	...	...	
Saretha	39	14·19	15·08	...	...	...	...	14·22	15·14	...	...	...	...	+
		20	20	...	...	...	...	21	18	...	...	...	...	
Cheni	15	12·08	12·66	...	...	...	...	12·11	12·44	...	...	...	..	+
		8	8	...	...	...	...	9	6	...	...	...	...	
Poovan	13	15·31	15·88	...	...	...	...	15·75	14·02	...	...	...	...	0
		9	9	...	...	...	...	11	7	...	...	...	...	
Naanal (all)	71	11·11	10·13	10·80	10·86	10·02	10·24	10·73	9·25	10·85	10·47	10·99	7·38	−
		36	36	18	18	18	18	65	6	45	20	3	3	
Naanal (*Saccharum spontaneum* class left out) ...	65	11·21	10·36	11·40	10·91	9·86	10·90	10·68	10·54	...	...	...	..	−
		33	33	16	16	17	16	50	20	...	...	...	...	
Vellai *Sacch. Narenga*	81	11·94	11·45	11·90	11·99	11·57	11·33	11·81	11·38	11·44	11·91	11·32	11·80	−
		42	42	21	21	21	21	52	34	11	41	30	4	

THICKNESS OF CANE AND SUCROSE.

Correlation 4.

The method of measuring the thickness of the cane has undergone a good many changes before a satisfactory one has been hit upon. At first ten or more canes were laid out and measured at the base, at the middle and at the highest mature joint (judged by hardness of rind). Measurements were also taken in two directions, namely, in the plane of the buds and at right angles to it. The latter, however, was soon discarded as, in reality, merely a measure of the ovalness in section, inherent in all sugarcanes. But these measurements even then were altogether too cumbrous in any large series and, after some changes, the following plan was adopted. All the canes of a seedling at crop time were laid out on a table and an average one was selected by eye measurement. This was then measured by calipers at the middle in the plane at right angles to the line of buds. The correlation is thus between the thickness of an average cane at middle and sucrose in the juice. The results are conflicting, and possibly no true correlation exists. But, in the general series, there is a somewhat marked negative tendency in most cases. The crosses, on the other hand, and *Naanal*, show the opposite tendency, namely, to a positive correlation. This may be in accordance with the fact that the thick stemmed parent is vastly richer in sucrose than the wild form with which it has been crossed. On the whole, beyond these tendencies, no definite correlation can be said to have been established between cane thickness and sucrose.

THICKNESS OF CANE AND SUCROSE.

	Number of seedlings	Equal classes as to numbers of seedlings.						Classes of equal differences in thickness of cane						Correlation
		Two classes		Four classes				Two classes		Four classes				
ittan	4	14·73 231	14·73 231	14·87 115	14·60 116	14·86 116	14·61 115	14·74 228	14·74 274	14·55 27	14·76 201	14·74 185·5	14·74 48·5	0
Karun ...	317	15·01 160	14·87 160	15·38 80	14·64 80	15·10 80	14·56 80	15·01 169	14·86 148	15·39 32	14·92 137	14·86 122	14·41 26	−?
dai Boothan ..	54	13·81 27	13·71 27	13·82 13·5	13·80 13·5	13·82 13·5	13·60 13·5	13·85 44	13·73 33	13·79 13	13·88 31	13·79 23	13·58 10	−?
Saretha	43	14·79 21·5	14·74 21·5	15·08 10·75	14·50 10·75	14·55 10·75	14·94 10·75	14·63 17	14·55 26	15·49 3·75	14·39 13·25	14·37 20	15·14 6	−?
Saretha (classes overlapping).	43	... ...	... ...	... ...	... ...	... ...	... ...	14·50 23	14·43 35	15·34 6	14·21 17	14·23 24	14·95 9	
Cheni	16	13·01 8	11·86 8	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	-
Poovan	11	15·11 6	16·92 6	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	+
Naanal (all) ..	71	10·43 36	10·79 36	9·86 18	11·00 18	10·68 17	10·89 18	9·15 11	10·87 60	... ...	9·13 11	11·10 30	10·75 30	+?
Naanal (*Saccharum spontaneum* class left out)	65	10·71 33	10·81 33	10·40 16	11·00 17	10·65 16	10·95 16	10·73 16	10·79 29	... ...	9·39 6	11·00 30	10·82 29	+?
Shakarchynia × *Succh. spont.*	...	9·30 31	9·50 31	9·15 15·5	9·45 15·5	10·28 15·5	9·78 15·5	9·50 59	9·96 40	9·16 20	9·14 39	10·02 31	9·77 9	+?
Vellai × *Succh. Narenga* ..	...	11·52 44	11·83 44	11·28 22	11·76 22	11·80 22	11·86 22	11·54 58	11·92 29	11·10 16	11·71 42	12·01 22	11·64 7	+

LENGTH OF CANE AND SUCROSE

Correlation 5.

The length of the cane was usually determined by taking ten or more canes out of the cut crop, measuring them accurately and striking an average of the ten. The canes were not measured until all the leaves had been stripped off, so that the total length above ground was easily obtained. The correlation is therefore between the average length of cane above ground (or height of cane) and sucrose. On the whole there seems to be a general tendency for the taller canes to have more sucrose. The matter is not, however, very convincing, in the absence of a marked correlation, because it is probable that ill grown seedlings, which would be of poor stature, would naturally give poor juice. This was certainly the case with the *Cheni* seedlings of 1911-13, all of which were analysed at crop time irrespective of extremely poor growth in some of them. The differences in sucrose are not very great between the extreme classes in the table. There is, however, one feature which deserves attention. In many cases (especially the larger series of *Chittan* and *Karun* seedlings), while the first three classes show a distinct rise in sucrose with increasing length, there is a fall in the fourth class of longest canes. This occurs in at least one of the classifications of each set of seedlings, where four classes have been possible, that is in all the sets excepting the small lots of *Cheni* and *Poovan*. It may therefore be postulated that the very tall canes, as a class, are distinguished by having less sucrose than those of moderate height, and, if we rule out this fourth class, there is a distinct positive correlation between length of cane and sucrose.

	Number of seedlings	Classes in equal numbers						Classes of equal differences in length of cane						Correlation
		Two classes		Four classes				Two classes		Four classes				
Chittan	451	14·31 226	15·31 225	13·97 113	14·65 113	15·47 113	15·14[1] 112	14·69 340	15·13 111	13·99 130	15·13 210	15·17 102	14·69[1] 9	+
Karun	330	14·57 165	15·25 165	14·00 82·5	15·15 82·5	15·40 82·5	15·10[1] 82·5	14·53 178	15·22 152	13·86 32	14·68 146	15·27 129	14·95[1] 23	+
Kalndai Boothan ..	54	13·45 27	13·99 27	13·21 13	13·68 14	14·34 14	13·61[1] 13	13·80 38	13·67 17	12·98 9	14·05 29	13·61 12	13·80 5	+ ?
Saretha	49	14·49 24	14·82 25	14·93 12	14·05 12	14·98 13	14·65[2] 12	14·36 43	14·38 7	14·49 24	14·99 19	15·18 4	13·31[1] 3	+ ?
Cheni	19	11·96 10	12·99 10	... ...	...	... ...	... ...	11·99 12	12·86 8	... ...	...	...	... ...	+
Poovan	14	14·94 7	16·00 7	... ..	...	... ...	... ...	15·62 8	15·27 6	... ...	...	...	... ...	0 ?
Naanal (all)	85	10·57 43	10·45 43	10·62 22	10·52 22	10·82 22	10·10[2] 22	10·54 53	10·56 32	11·15 6	10·42 47	11·23 16	9·68[2] 16	0 ?
Naanal (*Saccharum spontaneum* class left out).	79	10·71 40	10·55 39	10·66 20	10·75 20	11·03 19	10·09[1] 20	10·71 49	10·50 30	11·15 6	10·64 43	11·32 15	9·67[2] 15	0 ?
Shakarchyilia *Sacch. spont.*	67	9·52 34	9·67 34	9·39 17	9·64 17	9·71 17	9·64[1] 17	8·62 12	9·63 73	6·55 1	9·35 11	9·67 43	9·57[1] 30	+
Vellai *Sacch. Narenga*	81	10·81 44	12·36 44	10·68 22	10·95 22	12·52 22	12·21[1] 22	10·79 33	12·37 44	10·93 10	10·73 33	12·32 32	12·50 12	+

[1] Steady rise for first three classes and then a drop in the fourth.
[2] No steady rise, but third class highest.

CANE MODULE AND SUCROSE.

Correlation 6.

The module of the stem, as in the leaf, is the length divided by the thickness, but the resultant is one of averages and not of extremes as in the leaf measurements. There is a distinct positive correlation between cane module and sucrose in the larger series, *Chittan* and *Karun*, which is all the more to be noted when we remember the irregularities in the two preceding tables. The others of the general series fall more or less into line, excepting *Cheni*, whose length measurements have, however, been already stated to be untrustworthy (p. 180). It is noteworthy that the *Vellai* cross disagrees with its allies on other occasions, *Naanal* and the *Shakarchynia* cross, and shows a distinctly positive correlation. On the other hand, the two latter agree remarkably, in each case with a maximum in the second class followed by a decline in the third and fourth, a feature of perhaps no importance and merely a coincidence, but worthy of note in passing.

The measurements of leaf and stem have now been fairly fully studied in their relation to the quantity of sucrose in the juice. From this study it would appear that the seedlings, in any general collection, with higher sucrose content, would be marked out by rather narrow, short leaves, but with a relatively high leaf module, with canes which might be thick or thin but with a leaning towards the thin side, rather long but not very, and with a moderately high cane module. Where the seedlings are the result of a definite cross between two different species of Saccharum, these rules do not hold good. In fact, we should, according to the tables, look in these crosses for higher sucrose in thicker canes with broader leaves, but the results with the other factors are not clear and are contradictory among themselves, and we need more cases before any definite conclusions can be arrived at. It is probable that the tendencies will depend on the peculiarities of the parents in each separate case. The *Naanal* seedlings are an enigma, generally behaving as if they were the result of a cross, and it may be that, in these correlation studies, we may find a means of detecting whether any batch of seedlings is a general collection largely selfed or a set of crossed seedlings.

The leaf width being very easily measured, and having given good results thus far, it has been thought worth while to compare it with certain other characters, namely, thickness of stem, total weight of seedling at crop time and tillering power, the latter two bearing independently on the vigour of the cane.

CANE MODULE AND SUCROSE.

	Number of seedlings	Equal classes as to numbers of seedlings						Classes of equal differences in cane module						Correlation
		Two classes		Four classes				Two classes		Four classes				
Chittan	453	14·39	15·47	13·84	14·93	15·07	15·47	14·59	15·43	13·76	14·94	15·56	15·00	+
		227	227	113	114	113	114	334	119	99	235	93	26	
Karun	329	14·59	15·14	14·27	14·92	14·98	15·30	14·66	15·31	14·03	14·89	15·25	15·60	+
		164	165	82	82	82	83	244	93	65	179	76	17	
Kaludai Boothan ...	51	13·60	13·87	13·33	13·89	13·84	13·90	13·49	14·05	14·09	13·33	13·99	14·23	+ ?
		25	26	13	12	13	13	33	20	7	26	15	5	
Saretha	48	14·59	15·45	14·79	14·40	15·83	15·06	14·58	14·93	15·35	14·28	15·15	14·45	+ ?
		24	24	12	12	12	12	29	19	8	21	13	6	
Cheni	18	12·55	12·09	...	...	...	...	12·67	11·52	...	...	...	...	−
		9	9	...	...	...	...	12	6	...	...	...	...	
Poovan	14	13·45	15·01	...	...	...	...	13·48	15·60	...	...	...	...	+
		7	7	...	...	...	...	9	5	...	...	...	...	
Naanal (all)	84	10·91	10·12	10·89	10·94	10·37	9·88	10·97	10·15	10·98	10·97	10·58	9·25	−
		42	42	21	21	21	21	38	46	5	33	31	15	
Naanal (*Saccharum spontaneum* class left out).	78	10·97	10·31	10·90	11·04	10·35	10·26	11·00	10·31	10·98	11·00	10·58	9·48	−
		39	39	19	20	20	19	37	41	5	32	31	10	
Shakarchynia *Sacch spont.*	80	10·08	9·55	9·69	10·47	9·85	9·25	9·98	9·58	9·18	10·23	9·74	9·25	−
		40	40	20	20	20	20	41	62	9	32	42	20	
Vellai *Sacch. Narenga*	85	11·40	11·89	11·11	11·70	11·55	12·24	11·30	12·08	11·18	11·34	11·91	12·85	+
		44	44	22	22	22	22	55	33	16	39	27	6	

LEAF WIDTH AND THICKNESS OF CANE.

Correlation 7.

It is natural to assume that thick canes will have broad leaves, but the results of our studies have not always turned out as we expected them to, as in the case of leaf width and sucrose, where it was at first thought that the wider leafed forms, resembling the thicker canes of the tropics would have better juice. It is true that, the thicker the stem, the wider the base for leaf attachment; but we have noted in our study of the Punjab canes[1] that near relatives vary as to the extent to which the base of the leaf ensheathes the stem, and also that the relative width of lamina and leaf sheath varies a good deal at the point of junction. No help can be got from the previous tables where both the leaf width and stem thickness give or tend to give negative correlation with richness of juice. It was thought worth while, accordingly, to test the matter, and the results are given in the accompanying table. From its study we see that there is a very definite positive correlation between leaf width and thickness of cane. This is seen in all the seedlings of the general collection and in the *Vellai* cross. But in the other cross there is merely a tendency to a positive correlation and the differences in thickness in the classes of leaf width is remarkably small. In the *Naanal* seedlings, on the other hand, there is no trace of correlation either way, the whole of the classes varying slightly in an irregular manner, another case in which these puzzling seedlings are at variance with the other general collections. The *Poovan* seedlings are too few for any distinct correlation to be discernible.

[1] Barber, C. A. *Mem. Dept. Agri., India, Bot. Ser.* vol. VII, no. 1, p. 28.

	Number of seedlings	Equal classes as to numbers of seedlings						Classes of equal differences in leaf width						Correlation
		Two classes		Four classes				Two classes		Four classes				
Chittan	473	2·9	3·4	2·8	3·1	3·3	3·5	3·0	3·4	2·8	3·1	3·4	3·6	+
		236	237	118	118	119	118	363	209	71	289	174	35	
Karun	318	3·0	3·5	2·9	3·1	3·4	3·7	3·1	3·7	2·7	3·2	3·6	4·1	+
		159	159	79·5	79·5	79·5	79·5	192	126	29	163	112	14	
Kaludai Boothan	56	3·1	3·3	2·9	3·3	3·2	3·4	3·1	3·4	2·8	3·2	3·3	3·6	+
		28	28	14	14	14	14	32	24	8	24	19	5	
Saretha	43	1·6	1·8	1·5	1·8	1·8	1·9	1·7	1·9	1·5	1·8	1·8	2·1	+
		22	22	11	11	11	11	27	16	9	18	13	3	
Cheni	18	1·7	2·2	...	...	...	...	1·8	2·2	...	...	...	...	+
		9	9	..	..	..	..	11	5	...	...	...	...	
Poovan	11	3·1	3·0	...	...	...	...	3·0	3·4	...	...	...	...	0
		6	6	...	...	...	...	8	3	...	...	...	...	
Naanal (all)	71	Classes varying from 1·4 to 2·8, these variations being found in the *Sacch. spont.* class of six seedlings. The general result is the same whether these are included or omitted, and there is no correlation observable, all the averages being practically the same												0
Naanal (*Saccharum spontaneum* class left out).	65	Classes varying from 2·1 to 2·2 irrespective of leaf width.												0
Shakarchynia / *Sacch. spont.*	62	1·1	1·2	1·1	1·1	1·2	1·2	1·1	1·2	1·1	1·1	1·2	1·2	+ ?
		31	31	15·5	15·5	15·5	15·5	47	45	16	31	34	11	
Vellai / *Sacch. Narenga*...	79	1·7	1·9	1·6	1·8	1·9	2·0	1·7	1·9	1·5	1·7	1·9	2·0	+
		40	40	20	20	20	20	37	54	10	27	39	15	

[1] The lower figures indicate, as before, the number of seedlings dealt with and the upper figures give thickness of cane in centimetres.

LEAF WIDTH AND TOTAL WEIGHT OF SEEDLING.

Correlation 8.

The total weight of the seedling, one of the factors by which the vigour of growth may be judged, is taken only of those parts which are above ground, —all the canes and shoots at crop time. To get this figure requires a certain amount of management. In petty analyses canes are cut and they and their leaves are lost, while at harvest certain of the canes are not infrequently dried up or injured, introducing elements of doubt. Allowances have been made with regard to these facts. Even after this has been done, one would be prepared for the absence of definite results. But a study of the table will show that these doubts are unfounded, and there seems to be a very definite positive correlation between the width of the leaf and the total weight at harvest. This is perhaps what would have been expected, but it must be remembered that the narrow leafed North Indian canes have vastly greater tillering power than the thicker tropical ones, and consequently many more canes in the clump. We shall see how this factor comes out in the next table. In *Naanal* and the *Shakarchynia* cross there is a rather curious deviation, in that the first and last classes are the heaviest and the two middle ones considerably lighter, a fact which would not have been considered worthy of note, but for the unexpected agreement in the two sets of figures. The *Vellai* cross agrees with the general collection series and the positive correlation is very distinct.

LEAF WIDTH AND TOTAL WEIGHT.

	Number of seedlings	Equal classes as to numbers of seedlings						Classes of equal differences in leaf width						Correlation
		Two classes		Four classes				Two classes		Four classes				
Chittan	524	41[1]	45	37	45	45	46	42	46	34	43	45	50	+
		262	262	131	131	131	131	361	214	39	271	176	38	
Kaludai Boothan ..	46	40	55	35	45	52	59	41	56	35	43	49	84	+
		23	23	11	12	12	11	26	20	6	20	16	4	
Saretha	44	42	92	35	50	76	108	50	96	32	59	94	104	+
		22	22	11	11	11	11	28	16	9	19	13	3	
Cheni	16	42	67	...	...	...	...	48	65	...	...	...	...	+
		8	8	...	...	...	...	10	6	...	...	...	...	
Poovan	11	24	43	...	...	...	...	27	55	...	...	...	...	+
		6	6	...	...	...	...	8	3	...	...	...	...	
Naanal (all)	71	104	107	116	90	94	121	108	105	145	91	100	131	0
		36	36	18	18	18	18	23	53	7	16	42	13	
Naanal (*Saccharum spontaneum* class left out).	65	95	109	97	93	94	124	...	...	...	95[2]	94	131	+
		32	33	16	16	17	16	...	...	...	22	20	13	
Shakarchynia *Sacch. spont.*	62	99	92	111	87	79	105	99	93	113	94	88	117	0
		31	31	15·5	15·5	15·5	15·5	31	31	8·5	22·5	26	5	
Vellai × *Sacch. Narenga*	81	49	62	44	55	60	64	46	62	39	48	63	61	+
		42	42	21	21	21	21	40	54	11	29	39	15	

[1] The upper figures are total weight of seedlings in lbs

[2] Only three classes.

LEAF WIDTH AND TILLERING.

Correlation 9.

Tillering was judged by the total number of canes and shoots at crop time. Both are entered in the table, allowance being made as before for those removed during petty analyses. There is a general tendency, marked in the larger classes, towards a negative correlation between leaf width and tillering. But there is a remarkable exception in the case of the *Saretha* series, where there is a, just as strongly marked, positive correlation. This is unexplained, but it is worth while remembering that this series is practically the only one of indigenous North Indian canes, and further studies may show a difference between them and the tropical ones in this respect. It must also be remembered that it was possible to divide up the *Saretha* seedlings into habit classes (p. 133) and, on examination, it will be seen that the class with biggest seedlings had much the greatest weight and also greatest leaf width. It is possible that these habit classes, here so easily seen, dominate, and that they are absent in the thicker canes. The general result is, however, what we might expect on contrasting the tillering of tropical and North Indian canes, but the differences are much smaller than in that case. In the above remarks I have ignored the small *Pooran* class, for an examination of the tillering figures in the series shows the greatest fluctuations and the total number of seedlings is very small.

LEAF WIDTH AND TILLERING.

	Number of seedlings	Equal classes as to numbers of seedlings						Classes of equal differences in leaf width						Correlation
		Two classes		Four classes				Two classes		Four classes				
Chittan	489	14:7[1]	12:6	14:8	14:6	13:6	11:5	...	...	14:9	14:6	12:6	11:4	-
		244	245	122	122	123	122	...	...	72	296	183	38	
Karun	308	14:5	13:4	14:5	14:5	13:4	13:4	...	...	14:5	14:5	13:5	9:2	-
		154	154	77	77	77	77	...	...	48	176	77	13	
Kaludai Boothan ...	57	15:6:6:5	15:5:5	16:7	15:6	15:6	15:5	15:6	15:5	16:6	15:6	15:5	16:5	0
		28	29	14	14	15	14	32	25	8	24	20	5	
Saretha (canes and shoots together).	49	37	67	37	38	65	70	39	62	37	40	61	66	+
		21	25	12	12	13	12	21	28	5	16	21	7	
Cheni	18	47:14	41:13	...		...	...	49:13	37:12	...	...	...	...	
		9	9					11	7	...	...	...	...	
Poovan	13	10:7	13:8	Great fluctuation between adjoining classes.				11:7	14:7		...	...	...	+
		7:6	7:6					8:7	8:7	...	...	...	...	
Shakarchynia *Saech. spont.*	62	89	73	89	88	65	81	86	74	89	84	70	87	?
		31	31	16	15	15	16	47	45	16	31	34	11	
Vellai *Saech. Narenga*	81	33:11	32:16	34:13	32:10	33:15	32:17	32:14	32:17[2]	34:12	32:15	32:16	30:19	?
		40	41	20	20	21	20	40	54	11	29	39	15	

[1] The upper figures are the numbers of canes : shoots, at harvest.

[2] There appears to be a discrepancy between the figures for four classes and two classes here. This is due to the overlapping. In the 1st two classes the overlapping (and repeated) figure was unusually high, while in the 2nd two classes the overlapping (and repeated) figure was unusually low (*cf.* p. 168).

COLOUR OF CANE AND SUCROSE.

Correlation 10.

The study of various other possible correlations has been commenced, but the numbers of batches of seedlings tested are not as yet sufficient for definite results to have been obtained. The measurements thus far referred to have this advantage, that there is no doubt or difficulty in preparing the lists of variation. It is otherwise with less definite characters. The universal presence or total absence of any feature is rare in any batch of cane seedlings, almost all gradations being observable. Thus, with ivory markings on the stem, the seedlings vary from those with abundant markings, through all stages, to those without any at all, and it is extremely difficult to grade them into any series. Colour has, as already stated, special difficulties, but it has been carefully observed, because of the interesting fact that a striped parent has few or no striped seedlings. The analysis given below follows the classification laid down in the section of Variation in Colour of the canes (p. 145), namely, (1) Greens without any trace of red or vinous tinge, (2) Greens with vinous or brownish tinge, (3) Purples, Reds and Clarets, (4) Striped canes. A table is appended with the comparative sucrose content in the juice for all these colours in a number of batches of seedlings, and certain facts seem to hold generally, although the *Chittans*, with striped parentage, do not agree with the rest. From the table it appears that the greens usually have the lowest sucrose, the greens with brownish tinge the highest, closely followed by those with vinous tinge.

In *Karun* (337) greens are lowest but equal vinous, purple and red, and claret and brown are distinctly highest.

In *Saretha* (selfed 50) green is distinctly lowest, then red, then vinous and brown tinged, which are highest.

In *Naanal* (84) green is distinctly lowest and brown and vinous equal and highest.

In *Poovan* (only 14) green is distinctly lowest, then vinous equals purple and red and brown are much the highest, but the numbers are too small.

In *Kaludai Boothan* (56) green is slightly lower than brown and vinous, which are equal.

In *Chittan* red is slightly highest, claret slightly lowest, green, brown, vinous and purple being practically equal (486 seedlings, with striped parent).

In *Cheni* (25) greens absorb 80% of the whole, and comparisons are not well possible.

CORRELATION BETWEEN COLOUR OF CANE AND SUCROSE.

Parents	Number of seedlings examined	Greens with no brown, vinous, red, purple, or claret	Greens with vinous tinge	Greens with brownish tinge	Red	Purple	Claret
Chittan ...	468	14·77[1]	14·63	14·76	14·96	14·66	14·24
		264	38	67	15	65	19
Karun ...	337	14·53	14·63	15·46	14·53	14·68	15·52
		147	42	30	46	16	56
Kaludai Boothan	56	13·59	13·75	13·76	11·56	...	14·47
		24	24	6	1	..	1
Saretha ..	50	14·35	14·78		14·78	..	...
		23	4		23	...	...
Poovan ...	14	13·86	15·21	18·30	17·24	15·36	...
		4	4	2	1	3	
Naanal ...	84	9·87	11·03	11·03	...	...	..
		39	17	28	...	...	...

[1] The upper figures give sucrose % in the juice, the lower figures the number of seedlings in the class.

CONCLUDING SUMMARY.

In the course of the present paper, a large number of matters of minor interest have been introduced in the course of the narrative, and certain conclusions have been arrived at with regard to them. For the benefit of those who have not the opportunity of reading the somewhat long paper through, the following summary of these conclusions is appended. For details regarding the main issues, the paper itself must be consulted, as it has been found impossible to prepare a summary of many of these, because of the great amount of detail involved. Wherever possible, this detail has been presented in the form of tables, and the paper is copiously illustrated to render the descriptions clearer.

The first piece of successful work accomplished in the newly founded Cane-breeding Station was the production of seedling canes in India. This appears to have been repeatedly attempted, and the reason for previous lack of success appears to be that almost all the efforts were made in North India. Flowering of the sugarcane is rare there, and, when it occurs, there is, generally, sterility in the male organs. Flowering, furthermore, occurs in the cold weather, when it is less likely that seedlings can be raised. The flowering of the sugarcane decreases steadily in India as we proceed north and west, until it disappears entirely. The distribution of wild sugarcanes is discussed. *Saccharum spontaneum* occurs and flowers everywhere: *Saccharum arundinaceum* is abundant and flowers freely in Assam and is grown as far as the Punjab and Madras, but rarely flowers in these parts: *Saccharum Munja* is rare in Bengal and Assam and absent in the peninsula, but grows and flowers all along the submontane region, from Bihar to the Punjab: *Saccharum Narenga* is quite at home in Assam, covering huge areas, and appears to extend its habitat along the base of the Himalayas. Of these, all but *Saccharum arundinaceum* flower freely on the Cane-breeding Station and crosses have been obtained between *Saccharum Narenga* and *Saccharum spontaneum* and cultivated canes.

Male sterility is judged by closed anthers, for, when these are open, the pollen is well formed, while it is only immature and filled with starch when the anthers are closed. The percentage of open anthers is determined under the lens in all the arrows dealt with, this being simpler than the former method of testing male fertility, by iodine, for the presence of starch.

Flowering at Coimbatore occurs from October to December, although later cases are often met with. A study of the best method to induce flowering has resulted in the discovery that it depends chiefly on the time of planting. The best planting time for obtaining arrows is about November, but extends in some cases to as late as March-April. As the former is not the best time for cane planting on the station, "arrowing plots" have been instituted, planted in November, and these have been attended with marked success. Certain years, however, appear to be better for arrowing than others. For protection against foreign pollen the arrows are covered by fine muslin bags outside bamboo or iron cages, much as is done in Java work. Caging must be done before emergence of the inflorescense from its sheath, as some flowers have been seen to open their anthers before protrusion. When the analysis shows few open anthers, cross pollination can be attempted but, when many anthers are open, it is probable that most of the flowers are self fertilized, and crossing has not proved successful. It seems that there is some ground for assuming prepotency of the pollen in cane flowers, although this has not been definitely settled. The season of flowering at Coimbatore is in the heart of the north-east monsoon, a period of much rain and strong winds, and this adds to the difficulties, as the slightest permanent bend in the delicate flowering stalk seems to render the ovules infertile.

The sources from which cane arrows have been obtained are various. They are abundant in the ryots' fields locally, have been obtained from Bangalore, where flowering is excellent and also from Taliparamba on the west coast and Samalkota on the east. By various means, an increasing number of canes have been induced to flower on the station itself. A very large number of North Indian canes have now been collected there, and many of these have been made to flower, some for the first time. The farm is thus gradually becoming independent, and this adds a great deal to the efficiency of control as to parentage. Pollen is now being sent from a distance by post by the use of small gelatine capsules, and appears to retain its vitality longer than expected. Sugarcane seed has also been tested and has proved to keep good for a number of months.

The treatment of the collected arrows is now stereotyped. They are chopped-up and spread over an intimate mixture of finely powdered horse

manure (cleared of its weed seeds by germination) and river sand. This is placed in shallow pans, and watered frequently through the rose of a watering can and kept in the full sun. The seedlings begin to appear on the fourth day, but have been known to germinate only after a full month. They are pricked out if growing densely but, otherwise, are left in the pans for about three months, when they are separately potted out into a mixture of sand, red earth, leaf mould and loam. At six months, they are planted in pits, arranged in 10×10 squares for convenience of study. At first, these pits were very large but, owing to the extremely luxuriant growth of the seedlings, coupled with the suspicion that this lowered their sucrose content, the pits have been gradually reduced in size and the general treatment of the seedlings made less generous. On the other hand, it has been found difficult to grow the seedlings in the second year from cuttings, as the land on the farm is not yet fully fitted for sugarcane cultivation : and the trenches in which they are planted have been gradually made deeper and the land better treated. The land on the farm is slightly saline, from having been irrigated for thirty years by brackish water, and is only gradually being got into order. Advantage has been taken of this to test varieties of sugarcane and seedling canes for capacity to resist salinity and a " saline " plot is put down each year. The usual treatment in the farm of this saline land is to give a heavy dressing of tank silt, followed by a crop of *cholam* (*Andropogon sorghum*) or *ragi* (*Eleusine coracana*) and, lastly, a green manuring crop of field bean (*Dolichos lablab*) which has been found to grow excellently in the slightly saline soil. Practically the whole of the sugarcane land on the farm has now been treated in this manner, and the improvement in the growth of the canes is very marked. Still, soil difficulties have not been the least experienced on the new farm. The early and late canes of the clump, referred to in the Memoir on Punjab Canes, have been studied in a number of varieties with the idea of reducing errors in sampling, and a series of analyses of young canes " up to dead leaf " (*i.e.*, the lower part of the cane where all the leaves have died) have been made with the object of early separating the more valuable seedlings from the worthless ones.

It takes 18 months for the seedlings to mature. Owing to the restricted period of flowering and of obtaining seed, this brings them to harvest in June– a time which is at variance with the proper reaping and planting season on the farm land. The seedlings selected on their chemical analysis are cut up and planted out but they have again to be cut up and planted when six months old to bring them into line with the local custom, which is to plant in January to March. This is also the proper time for distributing selected seedlings

to other farms. It thus takes three years before a seedling can be distributed, but it is advisable to test it for two or three years more before doing so. The cane seedlings should thus be allowed to grow on the farm for at least five years, before they are ready for distribution and testing in special localities.

The vitality of the seedlings of different parentage has been found to vary a good deal. In some cases, such as "*Java*" from Bangalore, the fertility of the arrows appears to be very great, but the seedlings are so delicate that they die in thousands when very young, and comparatively few can be grown to maturity. In others, such as *Poovan* (Coimbatore) and *Fiji C*, their later growth is weak, and the plots at crop time are mostly bare. Other varieties, such as *Saretha* (Meerut and Aligarh), produce perfectly healthy seedlings and practically any number can be raised. The seedlings obtained by crossing cultivated canes with wild grasses (*Shakarchynia*, *Chin*, *Saretha* by *Saccharum spontaneum* and *Vellai* by *Saccharum Narenga*) are characterized by excessive vigour. Their sucrose content is, of course, low, being halfway between that of the parents. They flower freely but, in most cases, the anthers are persistently closed. By crossing the best of them (with 13-16% sucrose in the juice) with thick canes it is hoped that the way may be opened for producing new good canes, presumably of very hardy nature, with wild blood in their veins. This will depend, however, on the fertility of their female organs, there being some fear that the flowers may be altogether sterile in these hybrids.

An enumeration of the various seedlings obtained each year is given in tables, together with notes as to anthesis, parentage and ultimate fate. There has been a good deal of variation in the parentage each year, owing to the particular canes flowering. The ideal constantly aimed at is to obtain crosses between the various North Indian canes and thicker, better, tropical ones, with the object of producing varieties capable of being grown in North India under ryots' conditions. Success in this respect is dependent on simultaneous flowering of the desired parents and thus far, there have been very few cases of this. The current (1915) flowering season, however, promises very well as a large number of indigenous canes and introduced tropical ones are flowering together on the farm. Most of the former have infertile stamens which is a further augury of ultimate success.

The sucrose content of the seedlings has steadily increased during the past three years, as can be seen from the table on p. 162. During the current harvesting season, the sucrose in many seedlings has been very high, and about 250 which have produced over 18% of sucrose, having been selected

for growing on. The highest figure was in a seedling raised from *B 208*, which recorded 23·4% sucrose in the juice. Owing to the heavy analytical work and unusual rains during the ripening season, harvesting has, however, extended over a very long period, and many seedlings have been analysed when their optimum had passed. This has caused us to judge the sucrose in a seedling less by its analysis at harvest (bulk analysis) than by the highest recorded, whether in petty or bulk analyses. This method will give a slightly higher series of figures than if the bulk analyses were adhered to, but there is reason to believe that the seedlings grown on the farm are handicapped, and that many of them would give higher results if planted on old sugarcane land. This is clearly indicated in a table showing the sucrose content of some Madras seedlings which were grown in a number of different localities and under different conditions of water and soil (p. 155).

The variations in the morphological characters of the seedlings have been carefully noted, with the object of correlating them with richness of juice. General habit appears to be of the greatest use in classification of seedlings, as it has proved to be with varieties of cultivated cane. But there are special difficulties in observing it in young seedlings before planting out. Much attention has been paid to erectness, as many of the North Indian seedlings develop a prostrate or creeping habit. This objectionable character has been proved to increase when the seedlings are propagated by cuttings in the second year, but they vary much in subsequent recovery during their later growth. In some, they remain permanently low and spreading, while in others there is little trace of obliqueness at crop time. The whole of the varieties of Indian canes collected on the farm have been studied as regards this habit, which appears to be hereditary, and it has been found to be much more prevalent in indigenous Indian canes than in introduced ones. Two cases are given where a seedling has been followed from the germination of the cutting to the flowering stage, and the curve of growth is illustrated by a series of photographs of the successive stages of obliqueness. (Pl. XXII.)

Tillering, colour and striping of the leaves, width of leaves and canes, etc., are likewise dealt with and variations noted in seedlings of common parentage. The possible presence of "rogues," such as are found in other cultivated crops, is discussed, and especially such as have been lately described by Bateson and Pellew in culinary peas. Some of the exceptional seedlings in general collections and crosses have been selfed and, instead of splitting up as to parental characters, they appear to produce only rogues, a fact which has caused some surprise for the last two or three years. In these studies of

morphological characters, striping of the cane has received some attention, and it is shown that the seedlings of striped canes are rarely striped, but show a large range of single colours. Striping is, indeed, extremely rare in seedlings, and when present it is connected with striping of some of the earlier leaves. It appears to arise from one-coloured canes in the form of sports, and several instances of this, which have been observed, are recorded. The well-known splitting up of striped canes when planted out into canes of the component colours is illustrated by the mention of several varieties where this habitually occurs. Of the two colours composing the striping, green is far the commoner in such one-coloured sports.

In conclusion, an attempt is made at correlating some of the morphological characters of the seedlings with richness in the juice, dealing in each case with seedlings of common parentage. It is specially important that such correlations should be detected early in the life of the seedling, so as to avoid rearing useless plants, but there are special difficulties in the way, and the principle has been adopted of trying first to find such correlations in mature canes at crop time, and later, to attempt to correlate infant and mature characters. The first step alone has been tried at present and the following correlations have been studied between mature characters and sucrose in the juice, the results being given in the summary table appended :—correlation between the amount of sucrose in the juice and various leaf and cane measurements (width, length and module, or length divided by width) and colour of cane, and correlations between leaf width and thickness of cane, tillering power and total weight of seedling. In the studies on the colour of cane, the interesting fact has come to light that, in coloured and striped canes used as parents, approximately half of the seedlings are green. This appears to be true of the coloured parents in 1912-14, although there may be a larger proportion where the parent itself is green.

COIMBATORE,
December 3rd, 1915.

SUMMARY OF CORRELATIONS.

	Chittan	Karun	Kaludai Boothan	Saretha	Cheni	Poovan	Naanal		Shakarchynia *Saccharum spontaneum*	Vellai *Saccharum Narenga*	Notes
Number of seedlings dealt with ...	477	323	54	46	18	13	65	71	65	80	
Leaf width and sucrose ...					-	+[1]	+?	+	0	+?	[1] The numbers are so few that a single seedling has turned the scale.
Leaf length and sucrose ...									...	0	
Leaf module and sucrose ...	+	+?	+	+	+	0			...		
Cane thickness and sucrose ...	0	?	-?	?		+	+?	+?	+?	+	
Cane length and sucrose ...	+[2]	+[2]	+?[2]	+?[2]	+	0	0?	0?[2]	+[2]	+[2]	[2] In 10 out of 16 cases where four classes were possible, the curve is quite distinct and peculiar. There is a steady rise in the first three classes, followed by a fall in the fourth. In 4 of the remaining 6, the third class still has the highest sucrose (*cf* p. 150).
Cane module and sucrose ...	+	+	+?	+?	+	+	+	+	+	+	[3] In Naanal and Shakarchynia = *Saccharum spontaneum*, the curves are similar, there being a rise from the first to the second class, followed by a fall from the second to the fourth (*cf* p. 182).
Leaf width and thickness of stem	+	+	+	+	-	0	0	0	+?	+	
Leaf width and total weight ...	+	+	+	+	+	+	+	0[4]	0[4]	+	[4] In Naanal and Shakarchynia = *Saccharum spontaneum*, the first and fourth classes are much the largest and the second and third considerably lower (*cf* p. 186).
Leaf width and tillering ...			0	+		+	...	...	?	?	

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